THE NONHYDROSTATIC SHORT-RANGE MESOSCALE WEATHER FORECAST SYSTEM COSMO-RU : CURRENT STATUS and PROSPECTS

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10 July 2011, Tomsk

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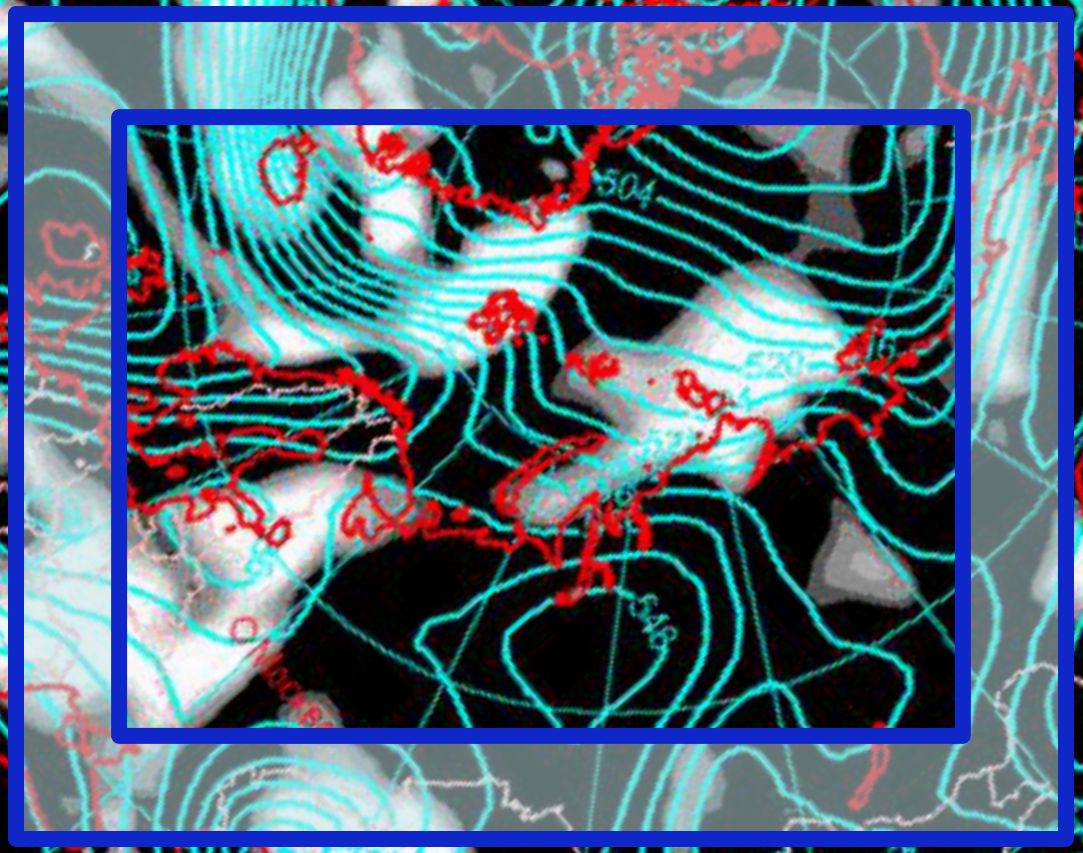
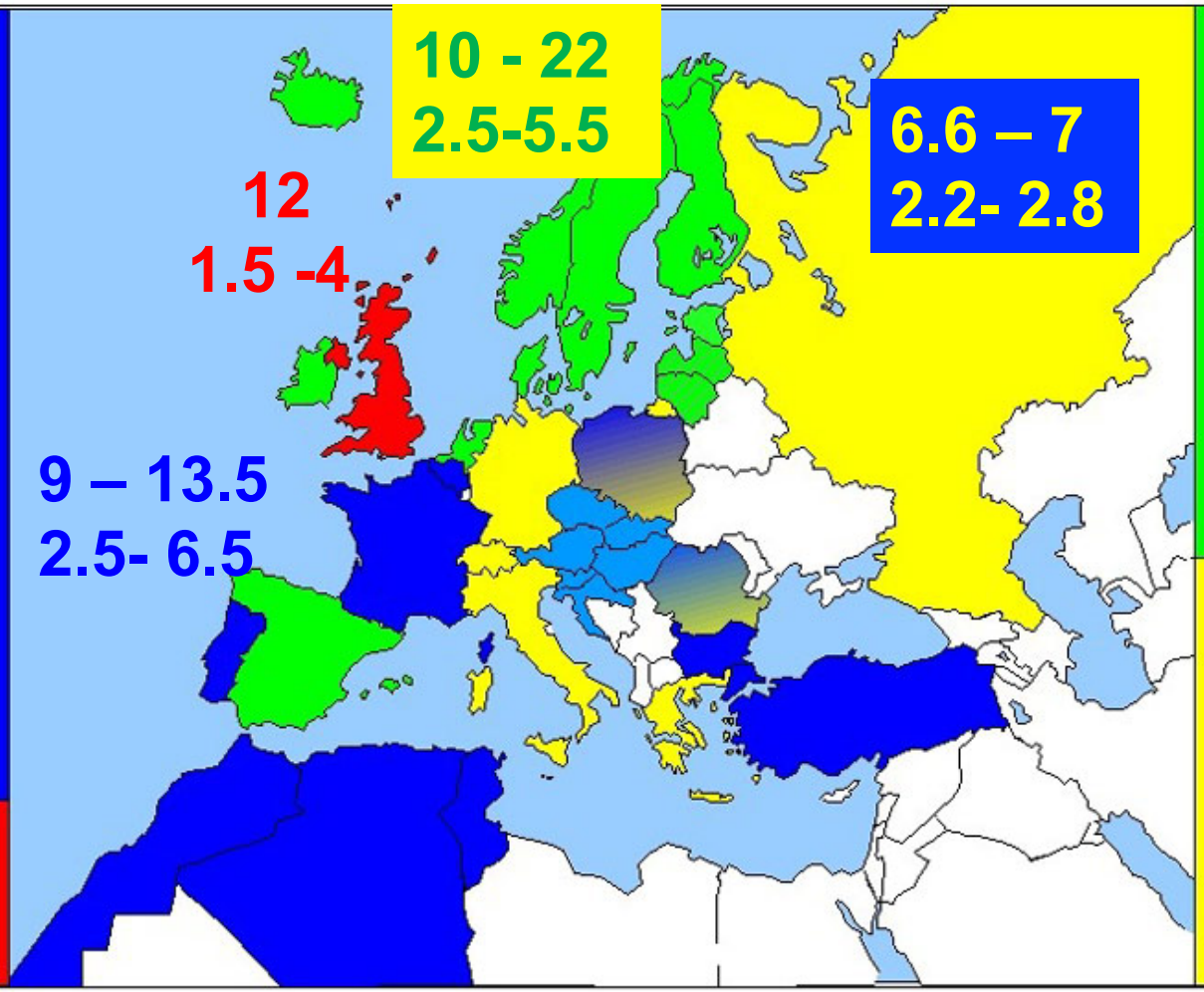
ПРОГНОСТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ДВИЖЕНИЯ АТМОСФЕРЫ НАД СЕВЕРНЫМ ПОЛУШАРИЕМ, СПЕКТРАЛЬНАЯ МОДЕЛЬ Т169



GRID STEPs (km) for 2 DOMAINS

SRNWP Consortia in Europe



ALADIN
Algeria
Belgium
Bulgaria
France
Morocco
Poland
Portugal
Tunisia
Turkey

Austria
Croatia
Czech Rep.
Hungary
Romania
Slovakia
Slovenia
LACE

UKMO
United Kingdom

HIRLAM
Denmark
Estonia
Finland
Iceland
Ireland
Netherlands
Norway
Spain
Sweden
(Latvia)
(Lithuania)

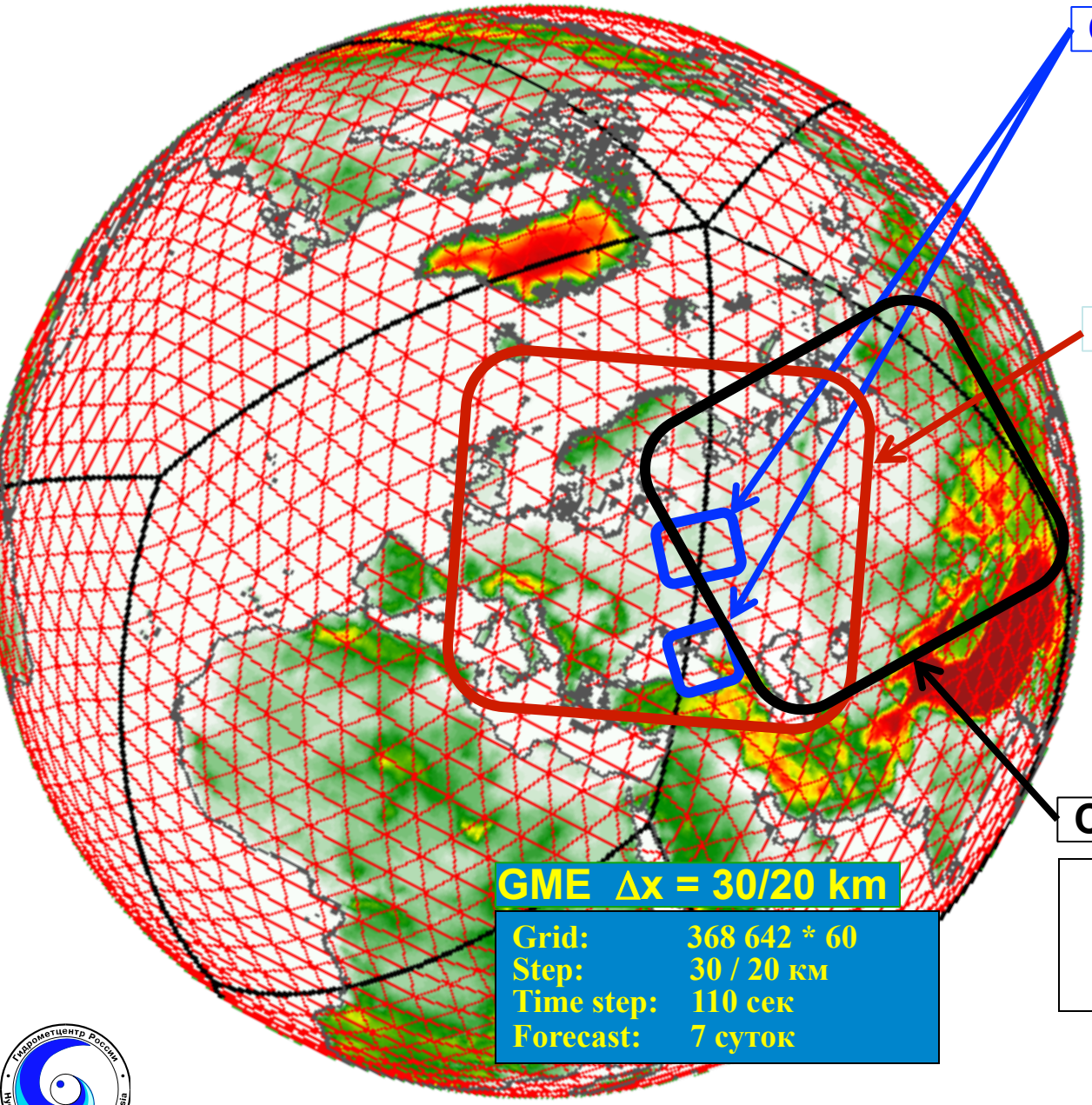
COSMO
Germany
Greece
Italy
Poland
Romania
Russia
Switzerland

Met Office

Compiled by Ulrich Shaetler , DWD, Oct. 2010

COSMO

SYSTEM COSMO-RU



COSMO-RU2 Δx =2.2 km

Grid:	420*470 * 50
Step:	2.2 км
Time step:	15 сек
Forecast:	24 час.

COSMO-RU7 Δx = 7 km

Grid:	700*620 * 40
Step:	7 км
Time step:	40 сек
Forecast:	78 час.

GME: initial and boundary data

COSMO-RUsib Δx =14 km

Grid:	360*250 * 40
Step:	14 км
Time step:	80 сек
Forecast:	78 час.

GME Δx = 30/20 km

Grid:	368 642 * 60
Step:	30 / 20 км
Time step:	110 сек
Forecast:	7 суток

System Equations COSMO-RU

$$T = T_0(z) + T'$$
$$p = p_0(z) + p'$$
$$\rho = \rho_0(z) + \rho'$$

$$\frac{\partial u}{\partial t} = -\left\{\frac{1}{a\cos\varphi}\frac{\partial E_h}{\partial \lambda} - vV_a\right\} - \dot{\varsigma}\frac{\partial u}{\partial \varsigma} - \frac{1}{\rho a\cos\varphi}\left(\frac{\partial p'}{\partial \lambda} - \frac{1}{\sqrt{\gamma}}\frac{\partial p_0}{\partial \lambda}\frac{\partial p'}{\partial \varsigma}\right) + M_u$$

$$\frac{\partial v}{\partial t} = -\left\{\frac{1}{a}\frac{\partial E_h}{\partial \varphi} + uV_a\right\} - \dot{\varsigma}\frac{\partial v}{\partial \varsigma} - \frac{1}{\rho a}\left(\frac{\partial p'}{\partial \varphi} - \frac{1}{\sqrt{\gamma}}\frac{\partial p_0}{\partial \varphi}\frac{\partial p'}{\partial \varsigma}\right) + M_v$$

$$\frac{\partial w}{\partial t} = -\left\{\frac{1}{a\cos\varphi}\left(u\frac{\partial w}{\partial \lambda} + v\cos\varphi\frac{\partial w}{\partial \varphi}\right)\right\} - \dot{\varsigma}\frac{\partial w}{\partial \varsigma} + \frac{g}{\sqrt{\gamma}}\frac{\rho_0}{\rho}\frac{\partial p'}{\partial \varsigma} + M_w + g\frac{\rho_0}{\rho}\left\{\frac{(T - T_0)}{T} - \frac{T_0}{T}\frac{p'}{p_0} + \left(\frac{R_v}{R_d} - 1\right)q_v - q_l - q_f\right\}$$

$$\frac{\partial p'}{\partial t} = \left\{\frac{1}{a\cos\varphi}\left(u\frac{\partial p'}{\partial \lambda} + v\cos\varphi\frac{\partial p'}{\partial \varphi}\right)\right\} - \dot{\varsigma}\frac{\partial p'}{\partial \varsigma} + g\rho_0 w - \frac{c_{pd}}{c_{vd}}p\cdot D$$

$$\frac{\partial T}{\partial t} = -\left\{\frac{1}{a\cos\varphi}\left(u\frac{\partial T}{\partial \lambda} + v\cos\varphi\frac{\partial T}{\partial \varphi}\right)\right\} - \dot{\varsigma}\frac{\partial T}{\partial \varsigma} - \frac{1}{\rho c_{vd}}p\cdot D + Q_T$$

$$\frac{\partial q_v}{\partial t} = -\left\{\frac{1}{a\cos\varphi}\left(u\frac{\partial q_v}{\partial \lambda} + v\cos\varphi\frac{\partial q_v}{\partial \varphi}\right)\right\} - \dot{\varsigma}\frac{\partial q_v}{\partial \varsigma} - \left(S_l + S_f\right) + M_{q_v}$$

$$\frac{\partial q_{l,f}}{\partial t} = -\left\{\frac{1}{a\cos\varphi}\left(u\frac{\partial q_{l,f}}{\partial \lambda} + v\cos\varphi\frac{\partial q_{l,f}}{\partial \varphi}\right)\right\} - \dot{\varsigma}\frac{\partial q_{l,f}}{\partial \varsigma} - \frac{g}{\sqrt{\gamma}}\frac{\rho_0}{\rho}\frac{\partial P_{l,f}}{\partial \varsigma} + S_{l,f} + M_{q_{l,f}}$$

$$\rho = p\left\{R_d\left(1 + \left(\frac{R_v}{R_d} - 1\right)q_v - q_l - q_f\right)T\right\}^{-1}$$

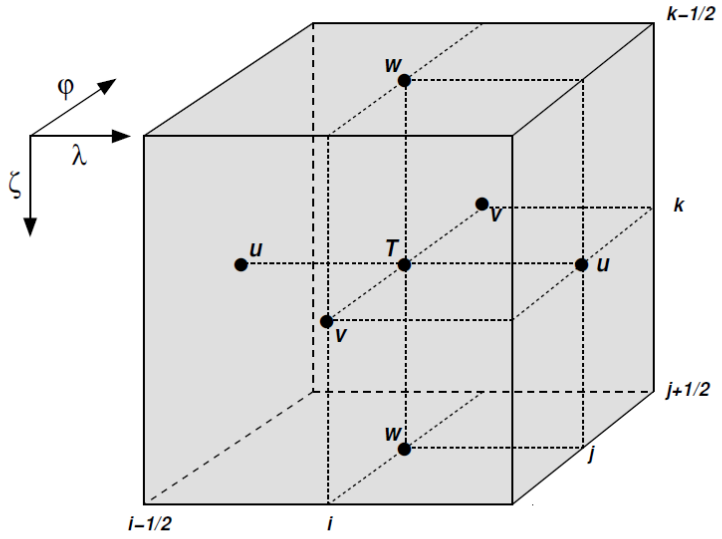
Система координат $(\lambda, \varphi, \zeta)$

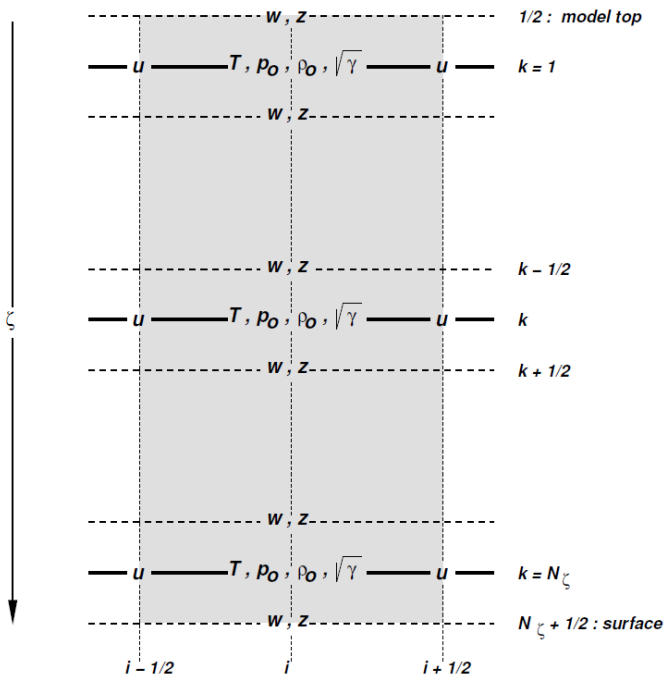
$$\dot{\varsigma} = -\frac{1}{\sqrt{\gamma}}\left(\frac{u}{a\cos\varphi}\frac{\partial p_0}{\partial \lambda} + \frac{v}{a}\frac{\partial p_0}{\partial \varphi} + g\rho_0 w\right)$$

$$E_h = \frac{1}{2}\left(u^2 + v^2\right) \qquad V_a = \frac{1}{a\cos\varphi}\left(\frac{\partial v}{\partial \lambda} - \frac{\partial(u\cos\varphi)}{\partial \varphi}\right) + f$$

$$D = \frac{1}{a\cos\varphi}\left\{\frac{\partial u}{\partial \lambda} - \frac{1}{\sqrt{\gamma}}\frac{\partial p_0}{\partial \lambda}\frac{\partial u}{\partial \varsigma} + \frac{\partial}{\partial \varphi}(v\cos\varphi) - \frac{\cos\varphi}{\sqrt{\gamma}}\frac{\partial p_0}{\partial \varphi}\frac{\partial v}{\partial \varsigma}\right\} - \frac{g\rho_0}{\sqrt{\gamma}}\frac{\partial w}{\partial \varsigma}$$

COSMO-RU: grid, components





Dynamics

- 3 time level split-explicit Leapfrog
- 2 time level split-explicit Runge-Kutta (several variants)
- 3 time level semi-implicit Leapfrog
- Relaxation

Physics

- Grid Scale Clouds and Precipitation (with or without 3D transport of precipitating particles)
  - warm rain scheme
  - 1-category ice scheme
  - 2-category ice scheme
  - 3-category ice scheme
- Radiation
- Subgrid Scale Turbulence Closure
  - 1-D diag. closure
  - 1-D TKE-based diagnostic closure
  - 3-D TKE-based prognostic closure
- Parameterization of Surface Fluxes
  - Standard bulk transfer scheme
  - TKE-based surface scheme
- Moist Convection
  - Tiedtke mass-flux scheme
  - Kain-Fritsch scheme
  - A scheme for shallow convection
- Soil Model (2 layers)
- Multi Layer Soil Model

Assimilation

- Observation processing
- Surface analysis
- Nudging of atmospheric variables and surface pressure
- Latent Heat Nudging

Initialization

- Digital filtering

Diagnostics

- Near surface weather parameters
- Mean values
- Meteographs
- Volume- and Area-Integrals
- Synthetic Satellite Pictures

I/O

- Grib
- NetCDF
- Restart

MODEL COSMO-RU07

LEVELS

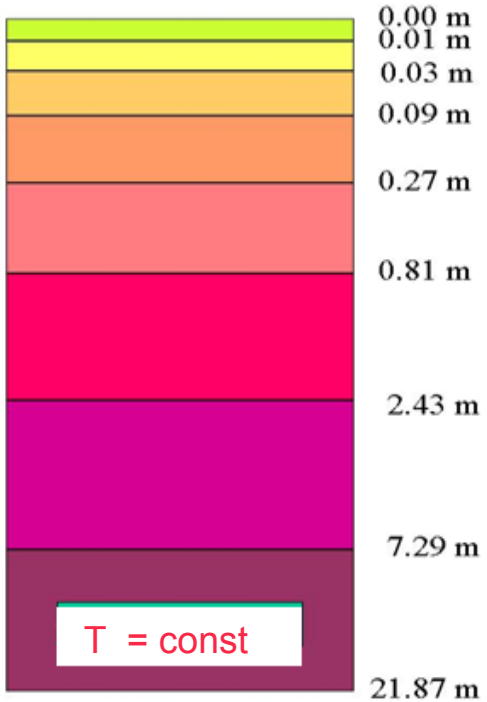
N	p, мм	z, м
0,5	20	23589
1	30	22300
8,5	203	11879
17,5	499	5569
Boundary layer		
27,5	830	1546
35,5	975	214
39,5	997	20
40	998	10
40,5	1000	0

Pvertical:

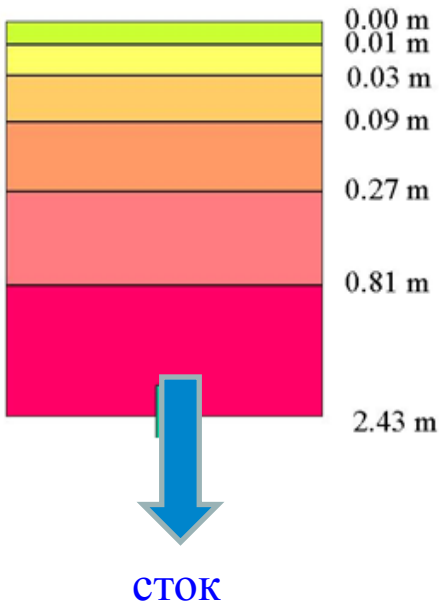
n-1/2	w, z
n	T,u,v, p_0
n+1/2	w, z

7 – LEVELS for SOIL

Temperature



HUMIDITY



LEVELS of COSMO-RU07 COSMO-RU02

7 N	Z	2.2 N	Z
1	23 589	1	22 000
3	18 834	4	19 085
5	15 978	8	15 587
7	13 763	10	13 998
9	11 879	13	11 807
11	10 211	15	10 470
13	8 711	18	8 643
15	7 355	20	7 539
17	6 132	23	6 050
19	5 035	25	5 162
21	4 060	26	4 750
23	3 201	29	3 630
25	2 456	32	2 680
27	1 823	35	1 891
29	1 295	38	1 254
31	871	41	757
33	542	43	500
35	303	45	299
37	143	47	150
39	49	49	51
41	0	51	0

Boundary layer
(< 1550 м)
12 levels
13levels

< 550 м
8 levels
8 levels

7 N	Z	2.2 N	Z
21	4 060	38	3 984
22	3 616	29	3 630
23	2 101	34	2 137
24	2 815	32	2 680
25	2 456	35	1 891
26	2 126	36	1 662
27	1 823	37	1450
28	1 546	38	1254
29	1 295	39	1 073
30	1 070	40	908
31	871	41	757
32	695	42	621
33	542	43	500
34	412	44	393
35	303	45	299
36	214	46	218
37	143	47	150
38	89	48	65
39	49	49	51
40	20	50	20
41	0	51	0

Method of the solution

A Description of the

Nonhydrostatic Regional Model LM

Part I :

Dynamics and Numerics

G. Doms and U. Schättler

LM_F90 2.18 November 2002

4.3.4 Outline of an Integration Step

As mentioned in the previous subsection, not all terms contributing to the tendency due to slow modes are considered by the forcing function f_ψ, which is used in the small time step sub-integration of the equations. The remaining terms are integrated subsequent to time splitting using the Marchuk splitting method (Marchuk, 1975).

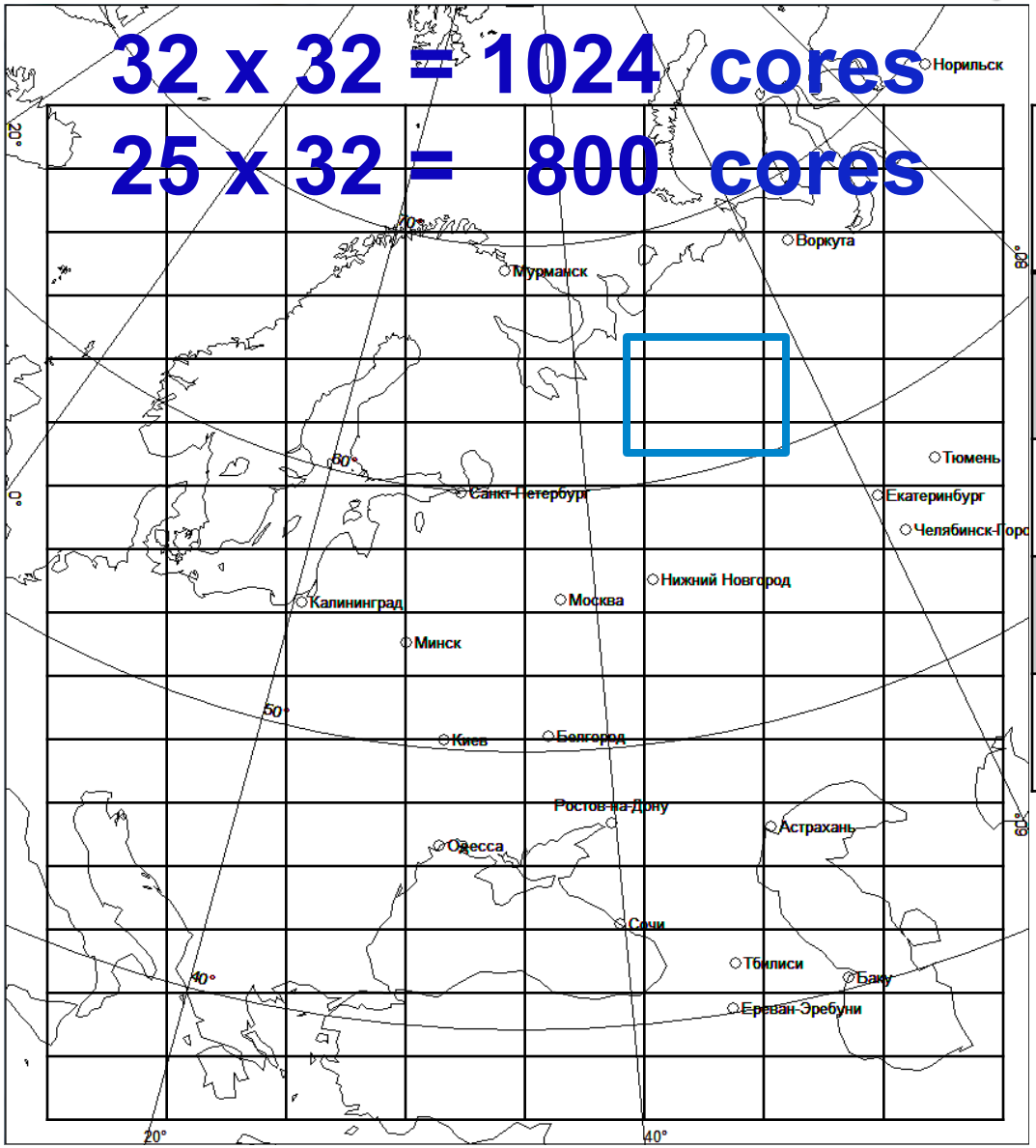
To illustrate this method, we rewrite the model equations in the symbolic form (4.31) as

$$\frac{\partial \psi}{\partial t} = s_\psi + f_\psi^{TS} + S_\psi^c + M_\psi^{CM} + M_\psi^{LB} + M_\psi^{RD} . \qquad (4.89)$$

s_ψ denotes the terms related to the fast modes and f_ψ^{TS} represents the slow-mode tendencies except for cloud condensation and evaporation (S_ψ^c), computational mixing (M_ψ^{CM}), lateral boundary relaxation (M_ψ^{LB}) and Rayleigh damping at the upper boundary (M_ψ^{RD}).

Marchuk, G. I., 1975: Numerical Methods in Weather Prediction. Academic Press, 227 p.

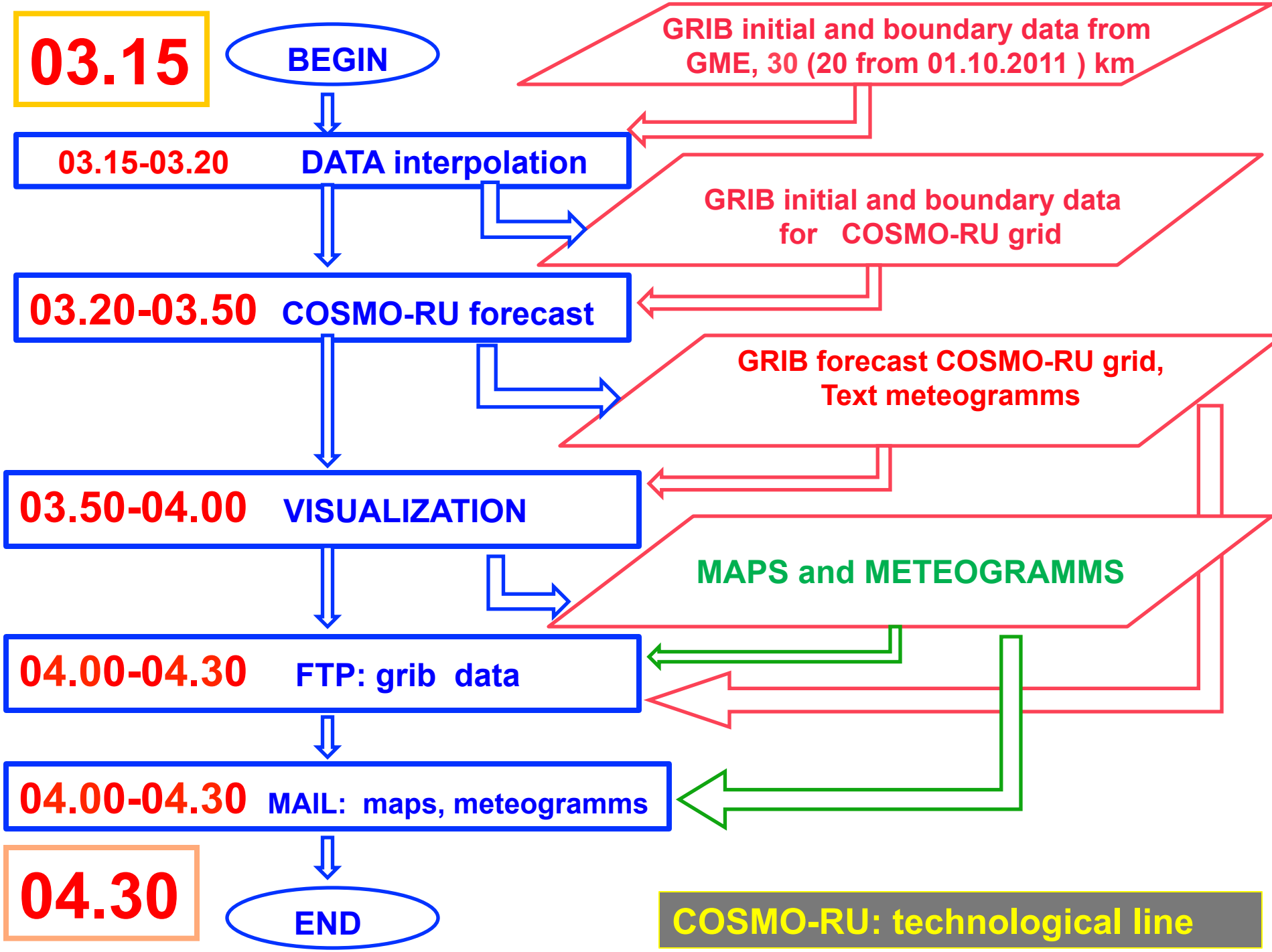
SUPERCOMPUTER: PARALLEL (MPI) CALCULATIONS



Time of the run for the 78 h forecast	
Cores	Time, min
256	59
2.0	1.8
512	33
2.0	1.7
1024	19

THE TIME of the RECEIVING of the OPERATIVE GLOBAL FTP-DATA

CENTER	START	FINISH	GRID STEP	INTERVAL FOR BOUNDARY DATA
COSMO	2 h 30 min	3 h 05 min	30 (20) km	every 3 (1) h
MetOffice UK (Exeter)	3 h 10 min	3 h 52 min	$1,25^0 * 1,25^0$ 135 км	every 12 h
NCEP	3 h 30 min	4 h 30 min	$0,5^0 * 0,5^0$ 55 km	every 6 h


03.15
BEGIN
GRIB initial and boundary data from GME, 30 (20 from 01.10.2011) km
03.15-03.20 DATA interpolation
GRIB initial and boundary data for COSMO-RU grid
03.20-03.50 COSMO-RU forecast
GRIB forecast COSMO-RU grid, Text meteogramms
03.50-04.00 VISUALIZATION
MAPS and METEOGRAMMS
04.00-04.30 FTP: grib data
04.00-04.30 MAIL: maps, meteogramms
04.30
END
COSMO-RU: technological line

Additial to fields for 41 model levels also fielda on 18 isobaric surfaces and for 14 z=const levels, maps and meteograms

COSMO-RU07: fields, maps, meteograms

N	гПа
1	25
2	50
3	75
4	100
5	150
6	200
7	250
8	300
9	400
10	500
11	600
12	700
13	850
14	900
15	925
16	950
17	975
18	1000

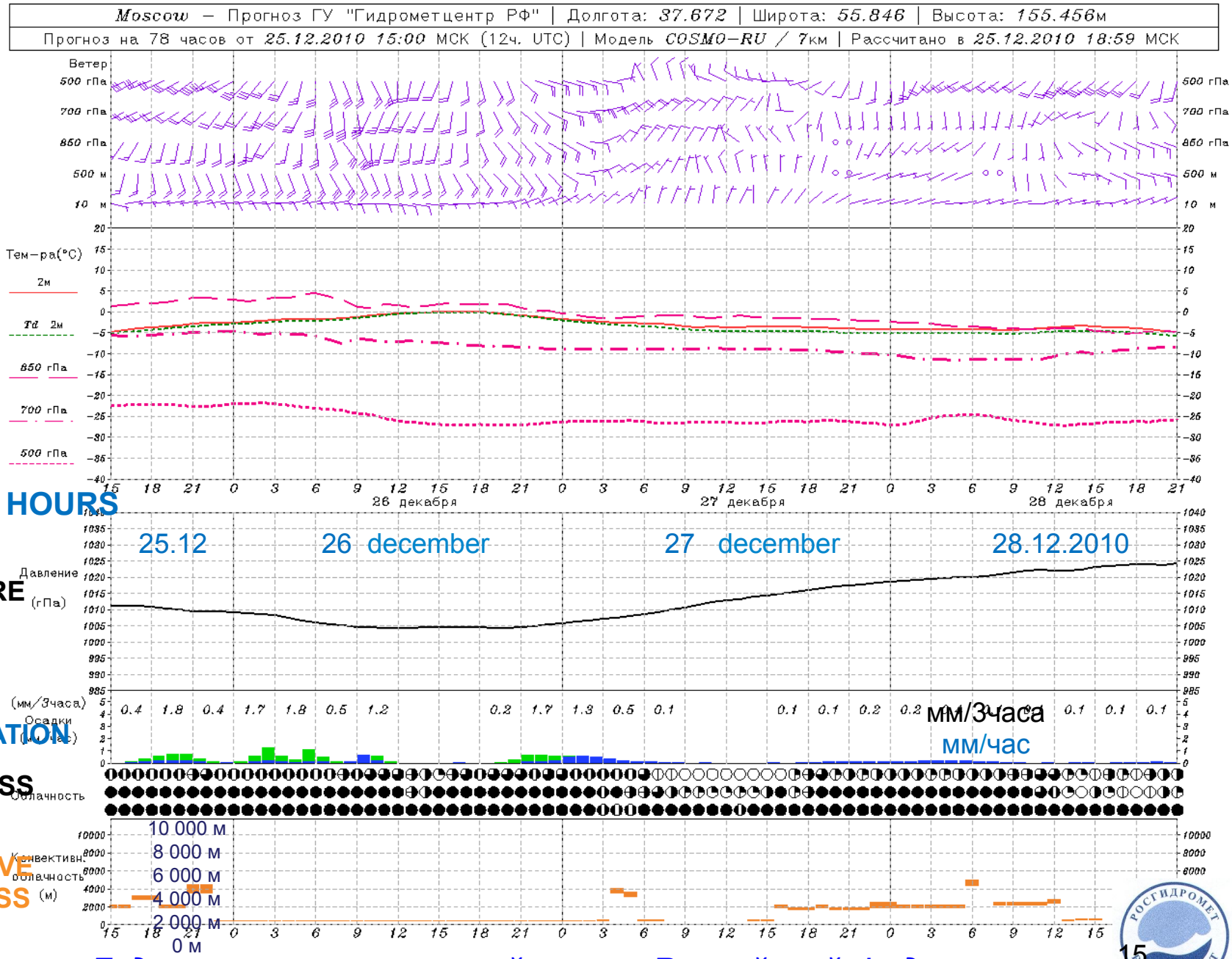
N	Z
1	20 000
2	19 000
3	17 000
4	15 000
5	13 000
6	12 000
7	11 000
8	10 000
9	9 000
10	8 000
11	7 000
12	6 000
13	5 000
14	4 000
15	3 000
16	2 000
17	1 500
18	1 000
19	600
20	500
21	300
22	100
23	50
24	10
25	2

2 times (04 and 16 h) it is special automatic preparing and mailing:

1.200 meteograms with information for every hour for different users about wind, T, Psea, clouds, preci[itation, convective clouds;

2.360 maps for every 3 hours for 3 domains T2м, Psea, precipitations, clouds, H500, T850, qusts of wind, height of convective clouds and so on.

COSMO-RU07: MOSCOW, 25.12.2010_15 – 28.12.2010_21 (msc)



WIND
500 гПа
700 гПа
850 гПа
500 м
10 м

T2м
Td2м
T850
T700
T500

DAY and HOURS

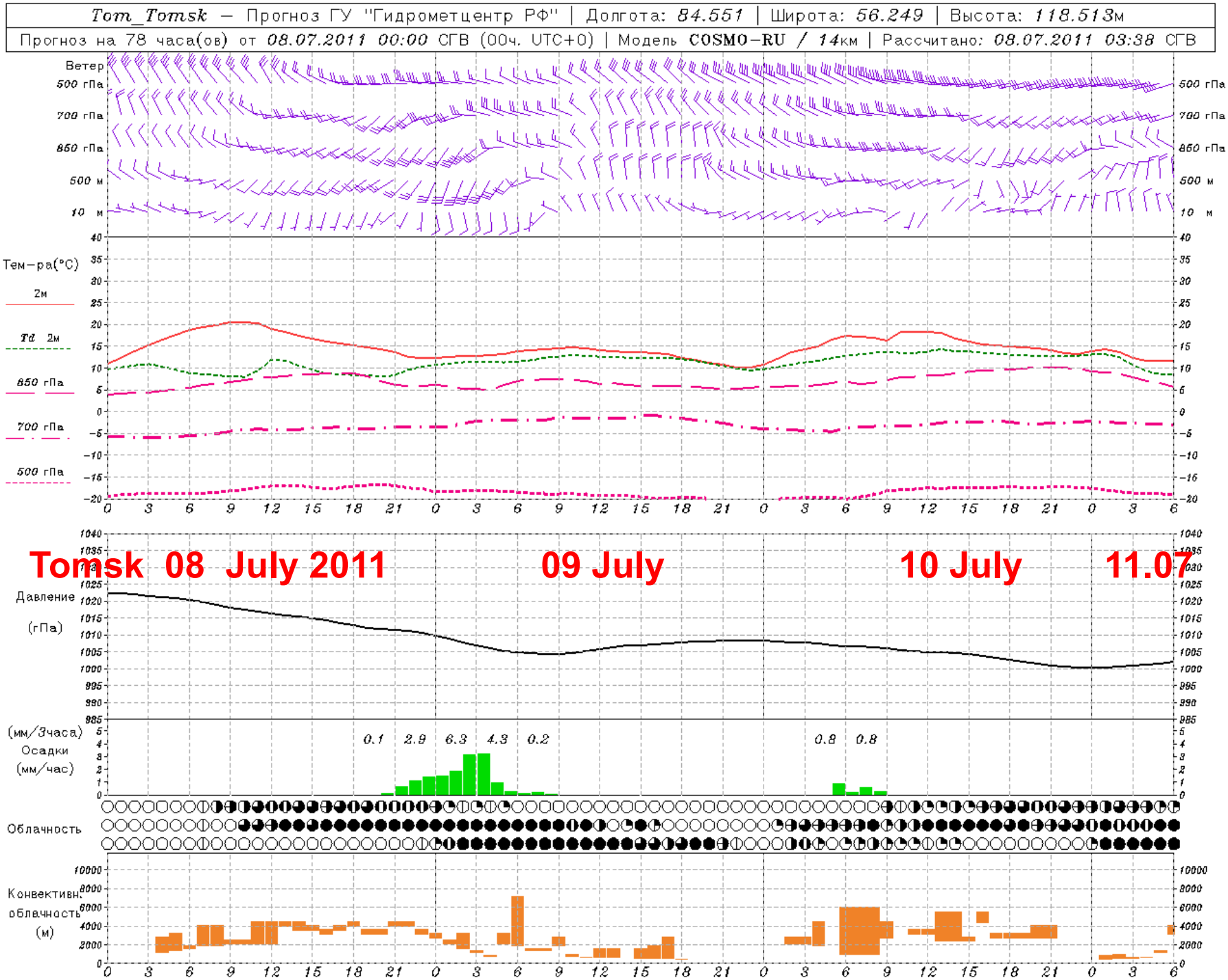
PRESSURE

PRECIPITATION

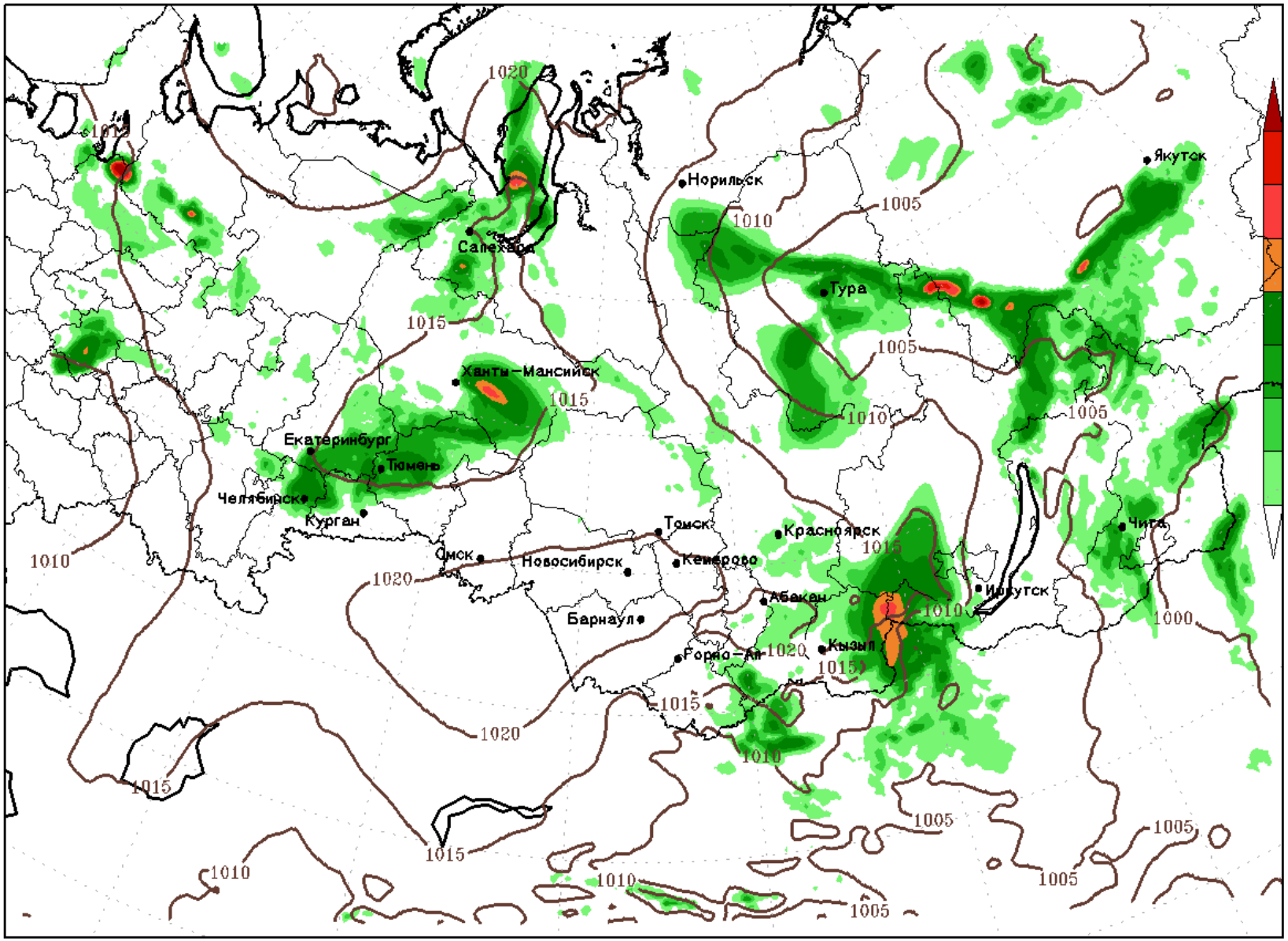
CLOUDSNESS

CONVECTIVE CLOUDNESS

Гидрометеорологический центр Российской Федерации


Tom_Tomsk – Прогноз ГУ "Гидрометцентр РФ" | Долгота: 84.551 | Широта: 56.249 | Высота: 118.513м
Прогноз на 78 часа(ов) от 08.07.2011 00:00 СГВ (00ч. UTC+0) | Модель COSMO-RU / 14км | Рассчитано: 08.07.2011 03:38 СГВ
Ветер
500 гПа
700 гПа
850 гПа
500 м
10 м
Тем-ра(°C)
2м
Td 2м
850 гПа
700 гПа
500 гПа
Tomsk 08 July 2011
09 July
10 July
11.07
Давление
(гПа)
(мм/3часа)
Осадки
(мм/час)
0.1 2.9 6.3 4.3 0.2
0.8 0.8
Облачность
Конвективн.
облачность
(м)

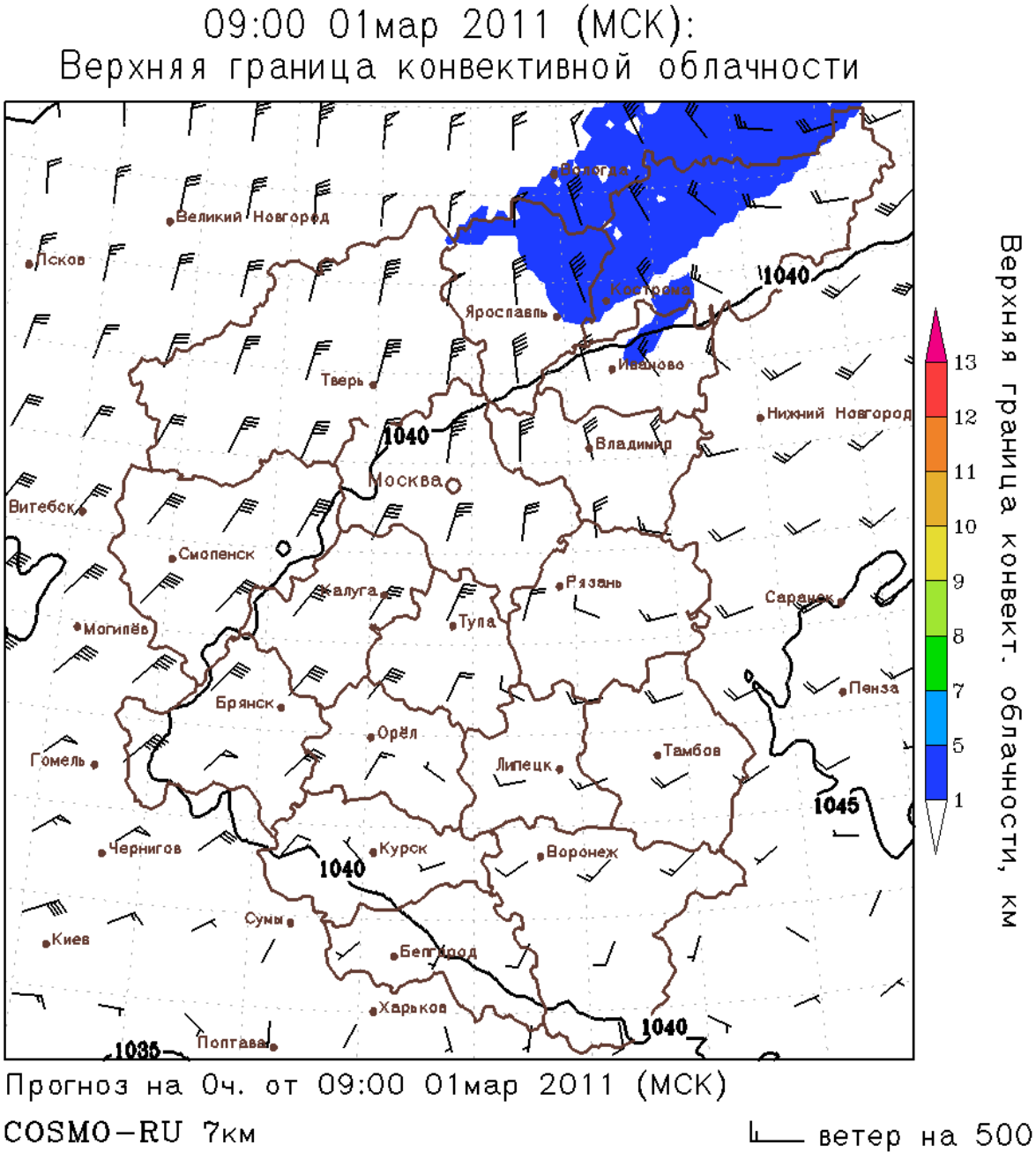
06:00 08июл 2011 (UTC+0):
Осадки за предыдущие 6 часов [мм]



Прогноз на 6ч. от 00:00 08июл 2011 (UTC+0)
COSMO-SIB 14км

Давление на уровне моря

COSMO-RU07: ETR, Initial data 01.03.2001 06 UTC (09 MSC)

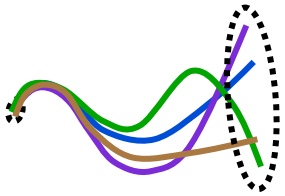
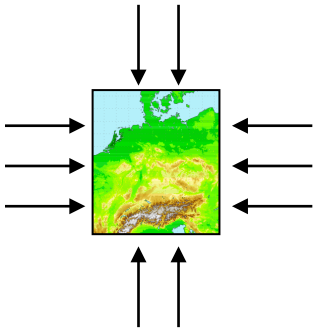
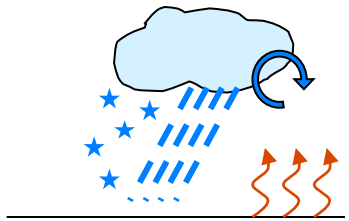


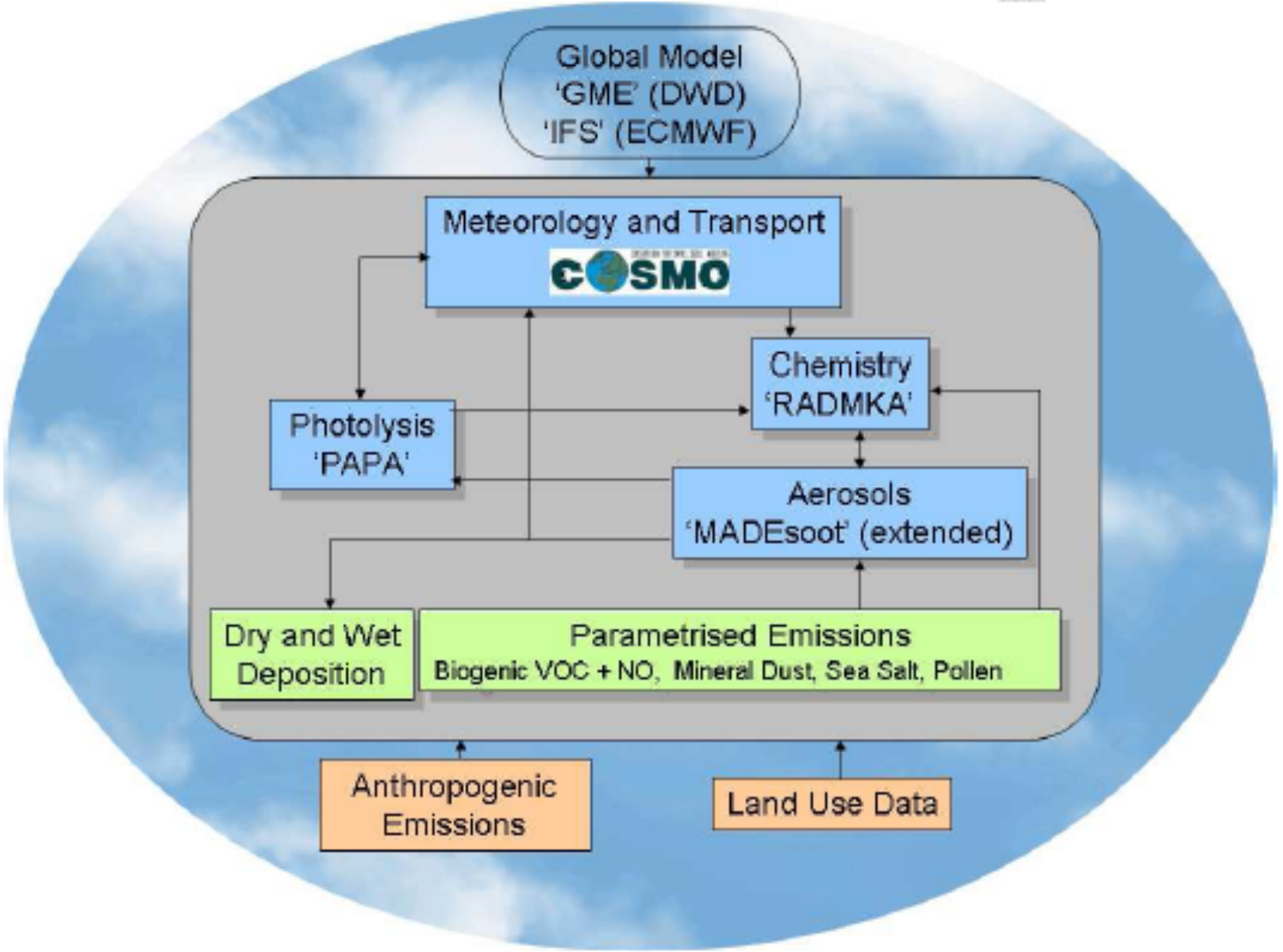
Развитие системы мезомасштабного негидростатического краткосрочного прогноза погоды COSMO-RU

1. Технологическая линия: Д.В.Блинов, Г.С.Ривин, И.А.Розинкина;
2. Снег : Е.В.Казакова, И.А.Розинкина;
3. Т2м : Г.С.Ривин, И.А.Розинкина, Е.В.Сапунцова;
4. Пограничный слой : О.В.Евтеев, В.Л.Перов;
5. VERSUS-2 : А.Ю.Бундель, А.В.Муравьев;
6. Усвоение данных : В.А.Горин, М.Д.Цырульников;
7. ART : А.А.Кирсанов, А.В.Ревокатова, Г.В.Суркова;
8. Сетки : Д.В.Блинов, Г.С.Ривин;
9. Ансамбли : Д.Ю.Алферов, Г.С.Ривин.

СОЗДАНИЕ АНСАМБЛЕЙ

Классификация изменений для определения неопределенности прогнозов

Начальные данные	Граничные данные	Физика модели	Метод решения
			3 time level split-explicit Leapfrog 2 time level split-explicit Runge-Kutta (several vari-ants)


Global Model
'GME' (DWD)
'IFS' (ECMWF)
Meteorology and Transport
COSMO
Chemistry
'RADMKA'
Photolysis
'PAPA'
Aerosols
'MADEsoot' (extended)
Dry and Wet
Deposition
Parametrised Emissions
Biogenic VOC + NO, Mineral Dust, Sea Salt, Pollen
Anthropogenic
Emissions
Land Use Data

ОСНОВНЫЕ ПРОЦЕССЫ В ART

- **Химические преобразования веществ в газовой фазе.**

Модель атмосферной химии RADMKA (модифицированная RADM2 (Stockwell, 1990, 1997 и др.) - 172 реакции, более 60 веществ.

- **Фотолиз.**

Модель фотолиза PAPA (Bangert, 2007);
Стандартные вертикальные профили константы фотолиза – модель STAR (Ruggaber, 1994);
Профили радиации для коррекции константы фотолиза – модель GRAAL (в блоке COSMO (Ritter, Geleyn, 1992))

- **Аэрозоли**

Модель MADEsoot (Riemer et al., 2003; Vogel, 2006, 2009 и др.)
Коагуляция, конденсация, нуклеация, осаждение, выведение, вымывание, химия

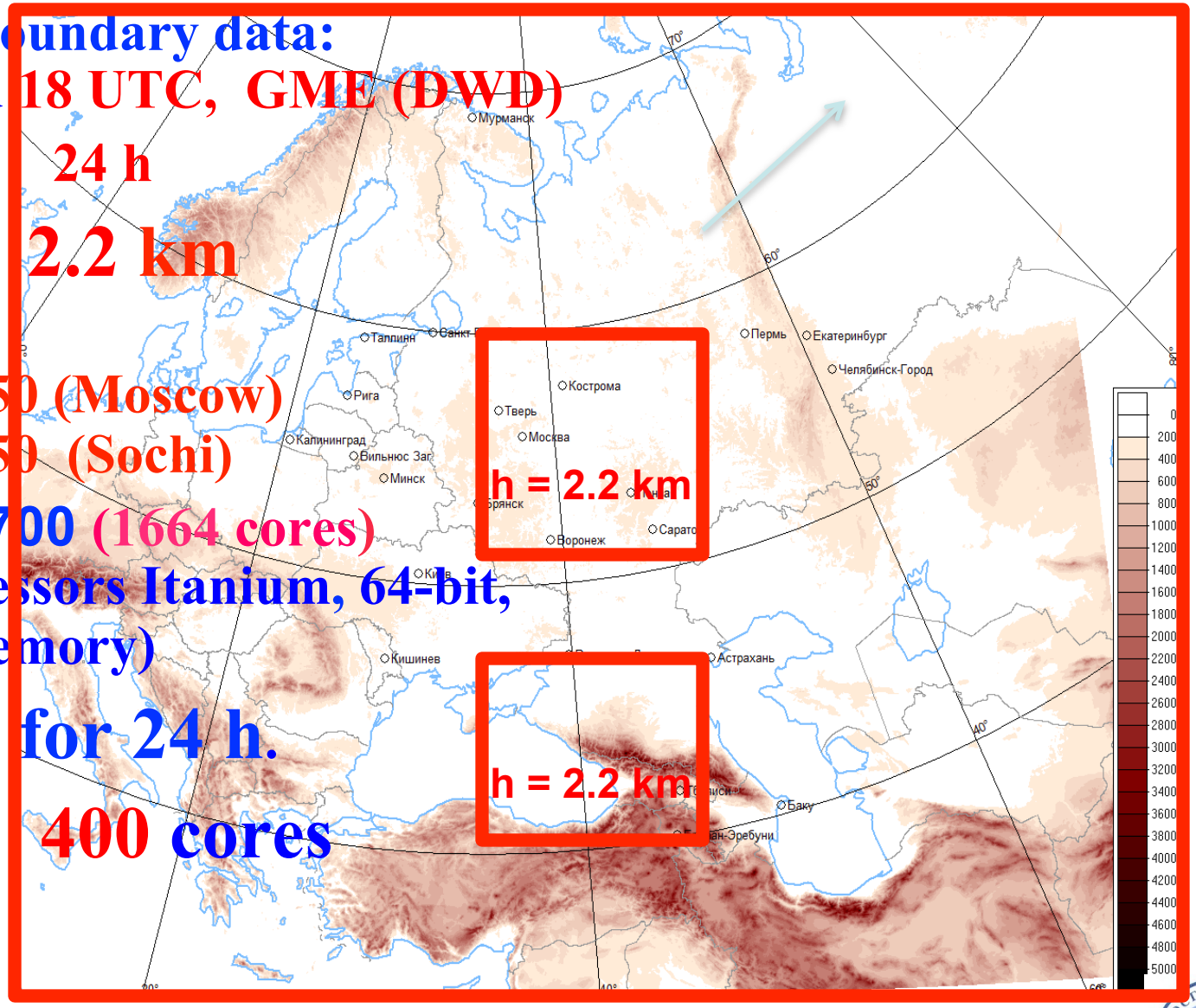
- **Природная эмиссия**

Морская соль, пыль, пыльца, биогенная эмиссия

- **Влияние на оптические свойства атмосферы**
- **Гетерогенные реакции**

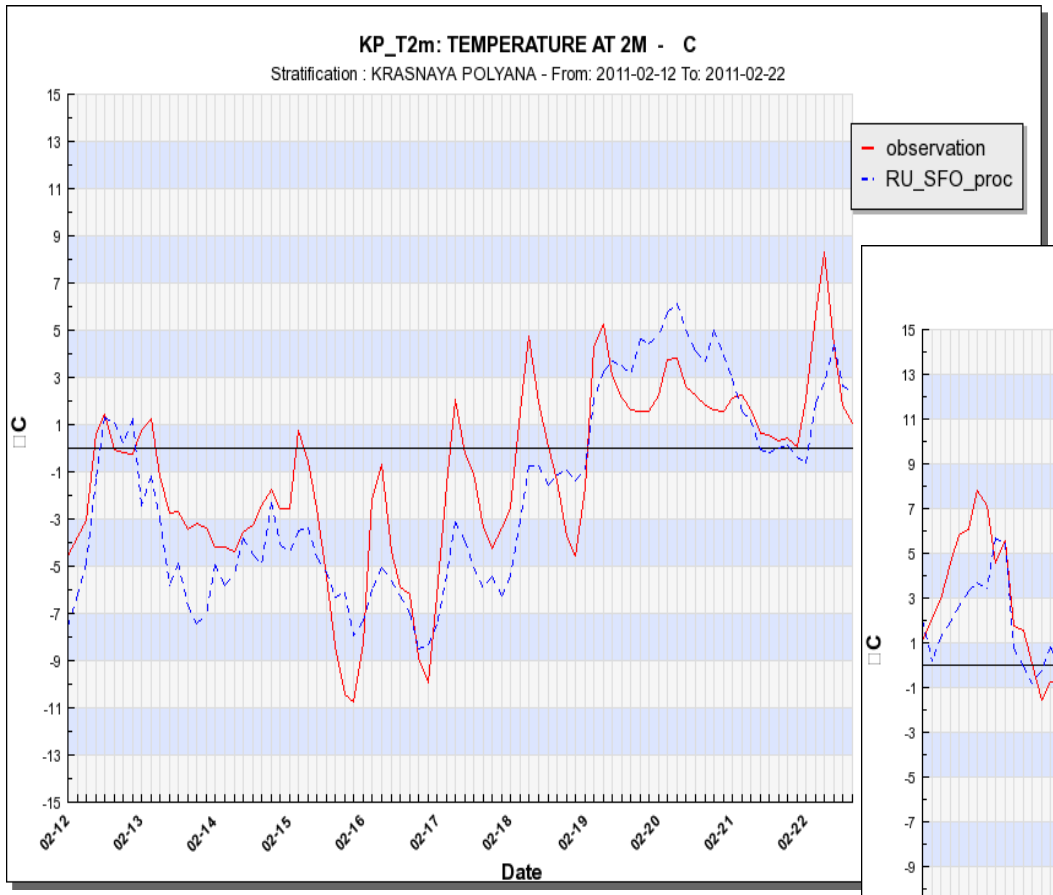
COSMO-RU02: domain, time of run with MPI

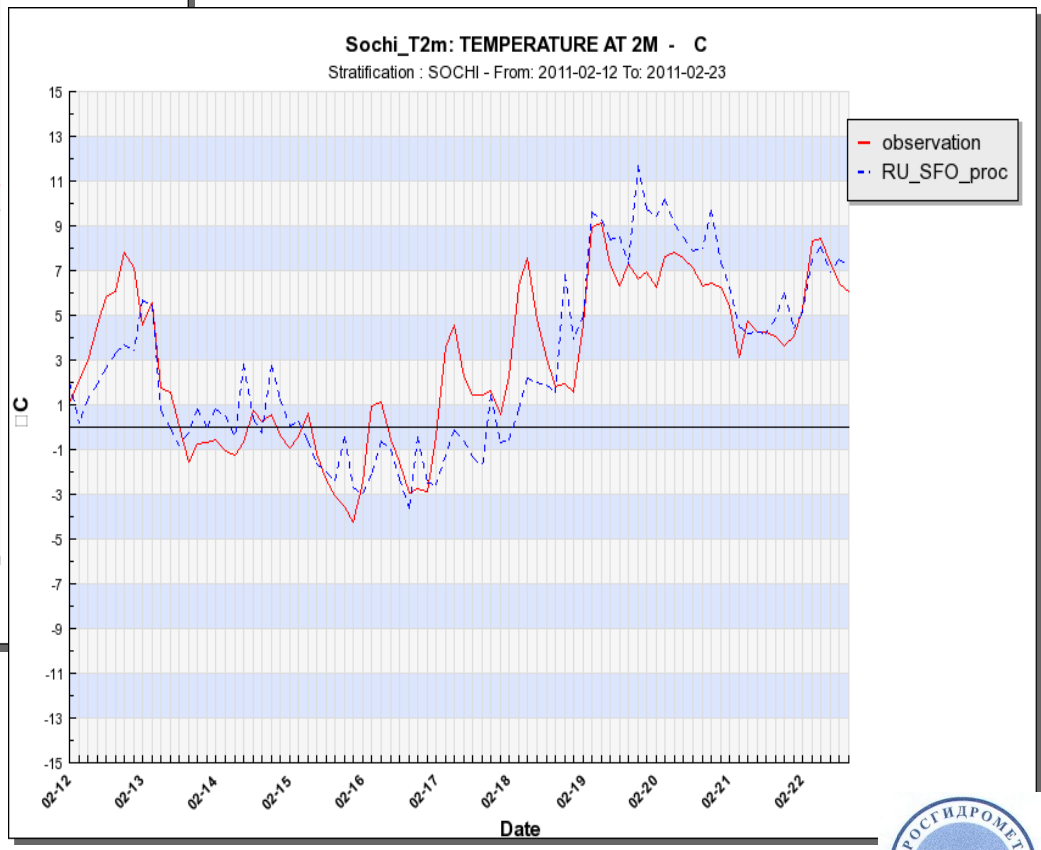
- **Initial and boundary data:**
  00,06,12 and 18 UTC, GME (DWD)
- **Forecast: 24 h**
- **Grid step 2.2 km**
- **Grid:**
  420 * 470 * 50 (Moscow)
  420 * 420 * 50 (Sochi)
- **SGI Altix 4700 (1664 cores)**
  (832 processors Itanium, 64-bit, 3,3 Tb memory)
- **Run time for 24 h.**
  40 min: 400 cores



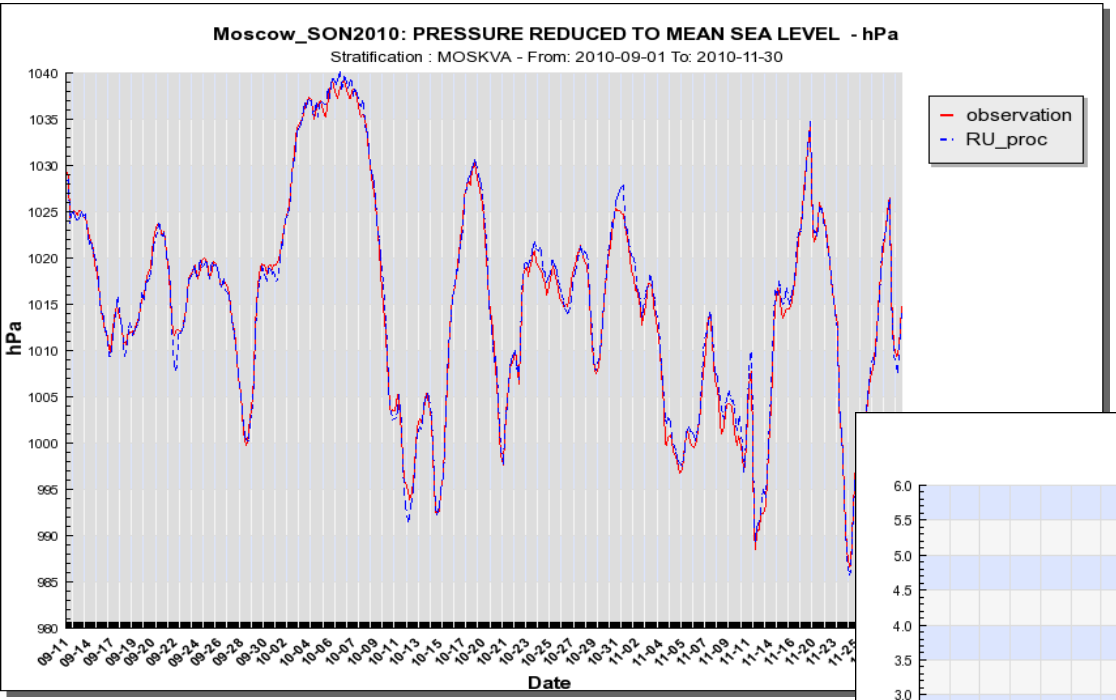
Гидрометеорологический центр Российской Федерации

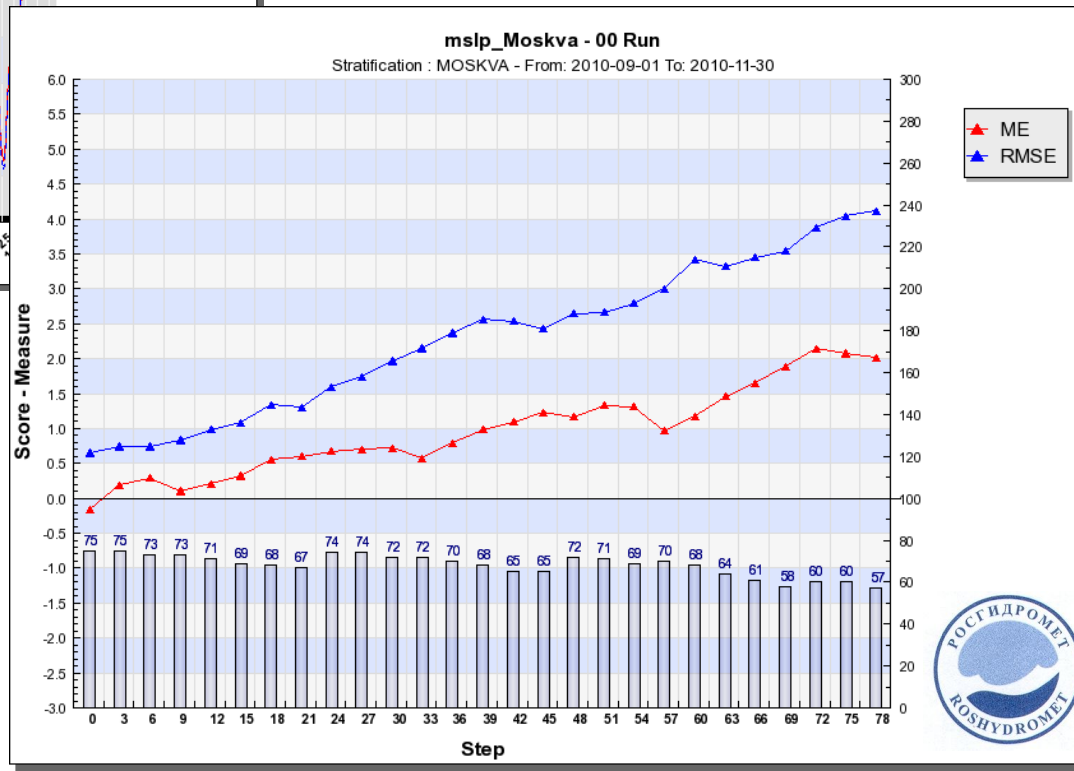
COSMO-RU2, 12-23 February 2011, T2m, Krasnaya Polyana, Sochi



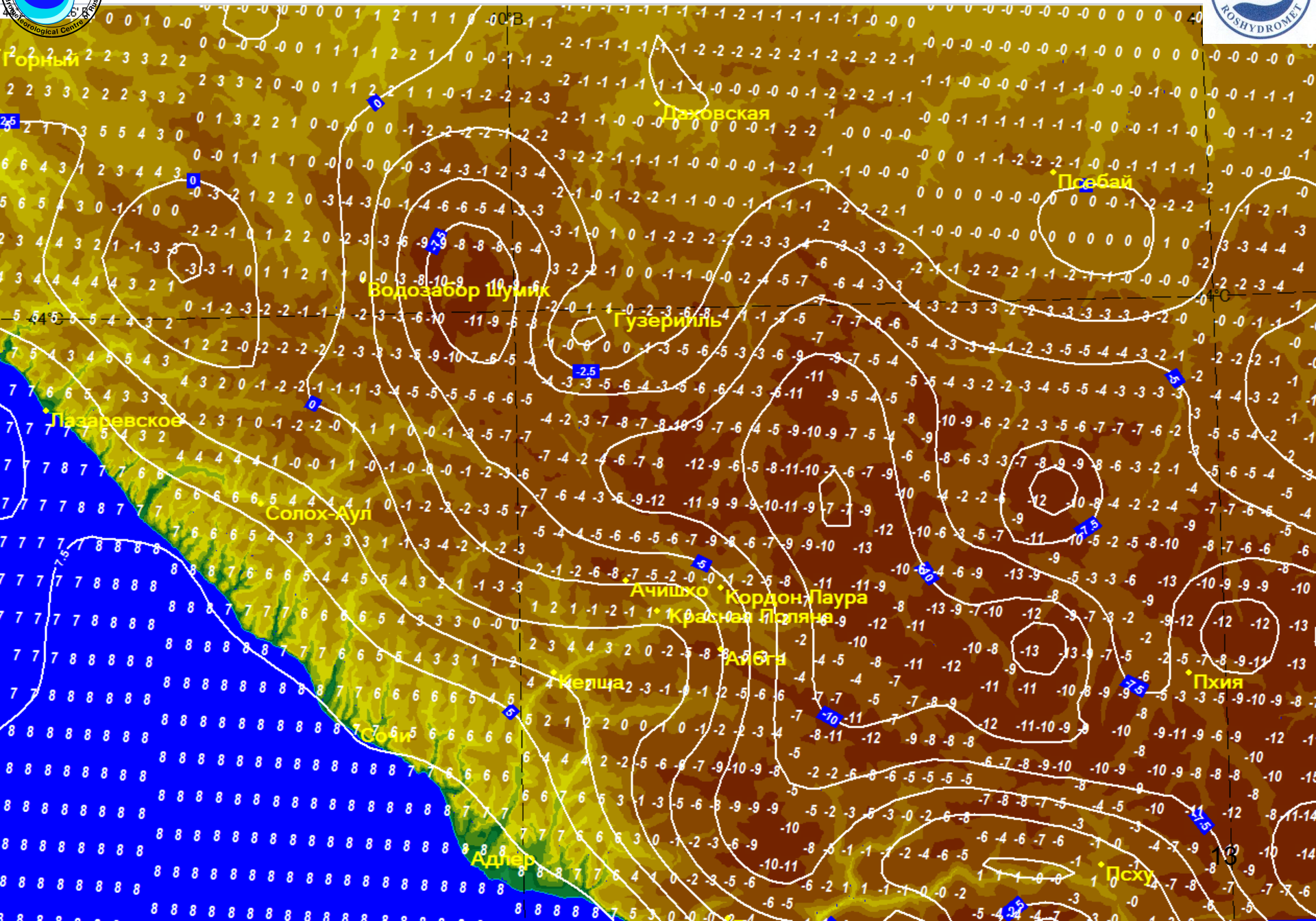


COSMO-RU02,
September-November 2010, Psea, Moscow

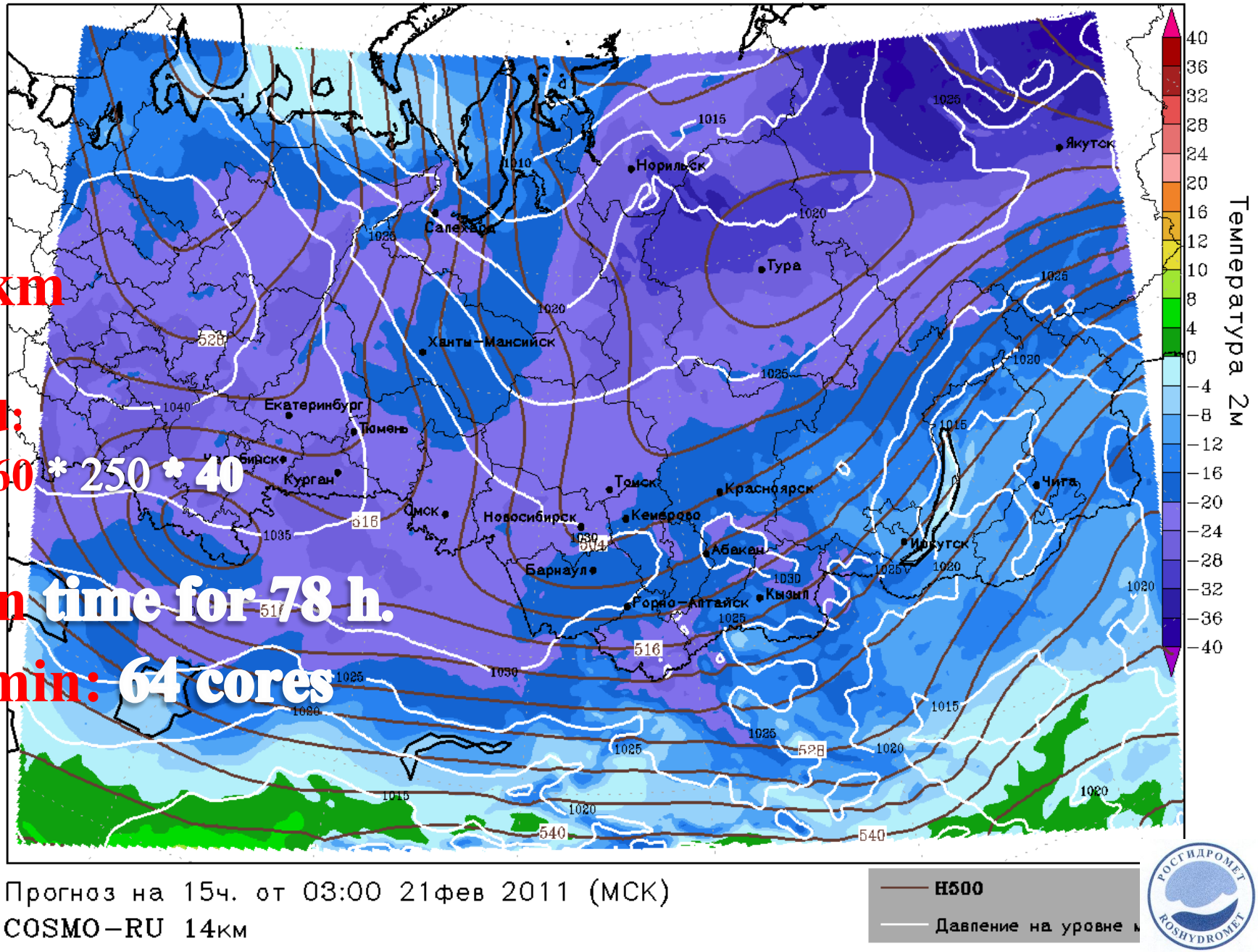




COSMO-RU02, SOCHI-2014, T_{2m} , 28.01.2011_15MSC

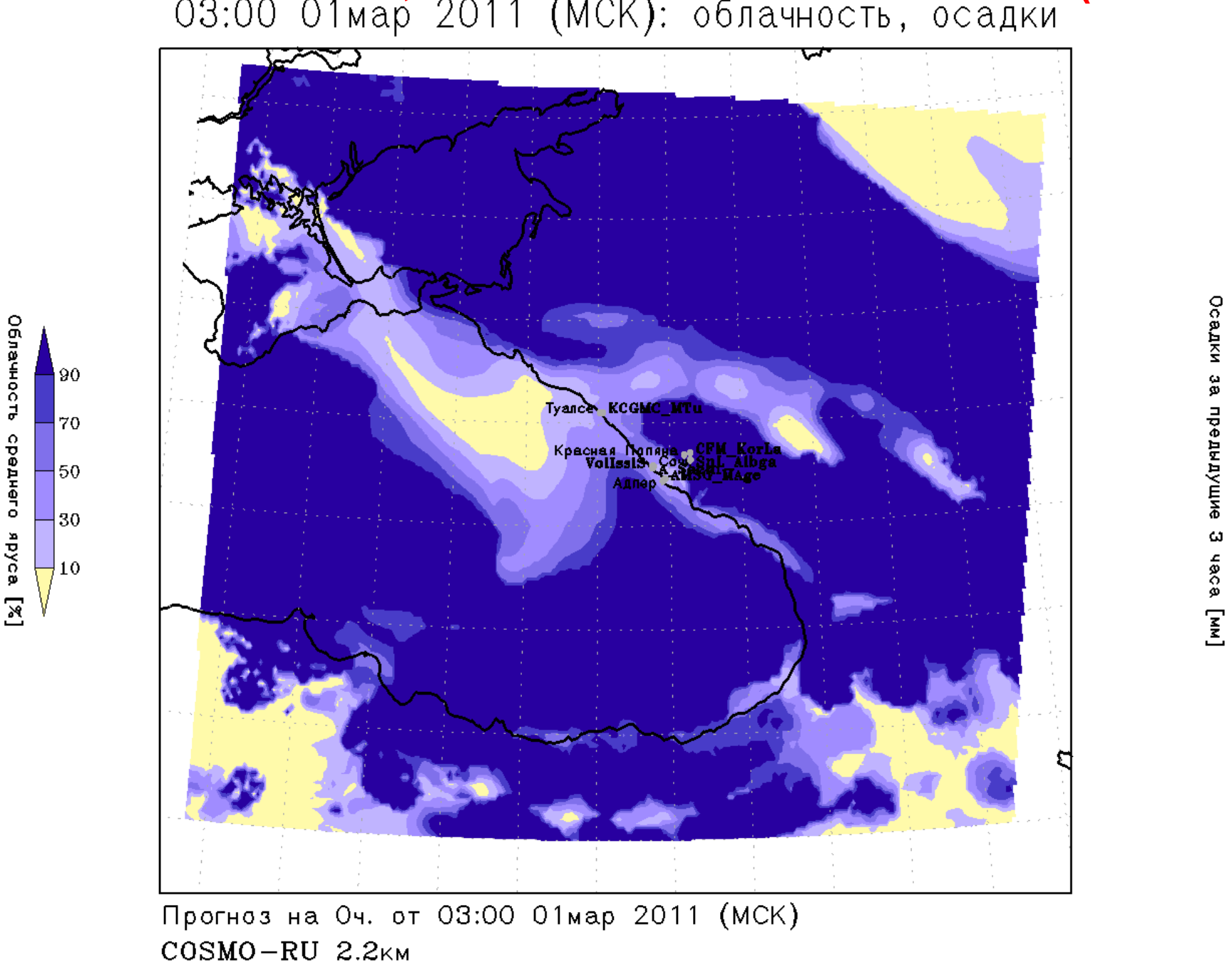


COSMO-RU14: Siberia, time of run with MPI

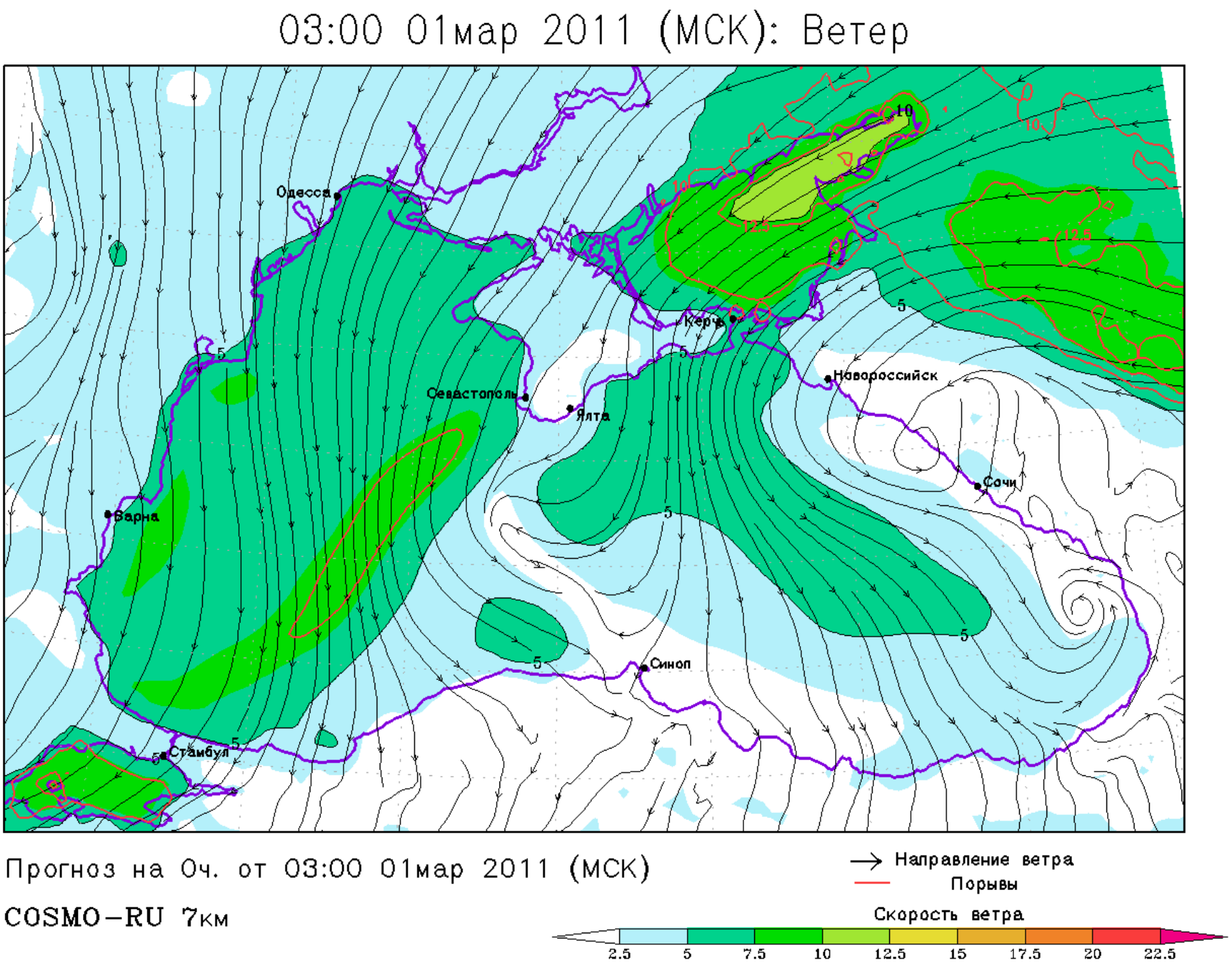


- Grid step **14 km**
- Grid: **360 * 250 * 40**
- **Run time for 78 h.**
- **27 min: 64 cores**

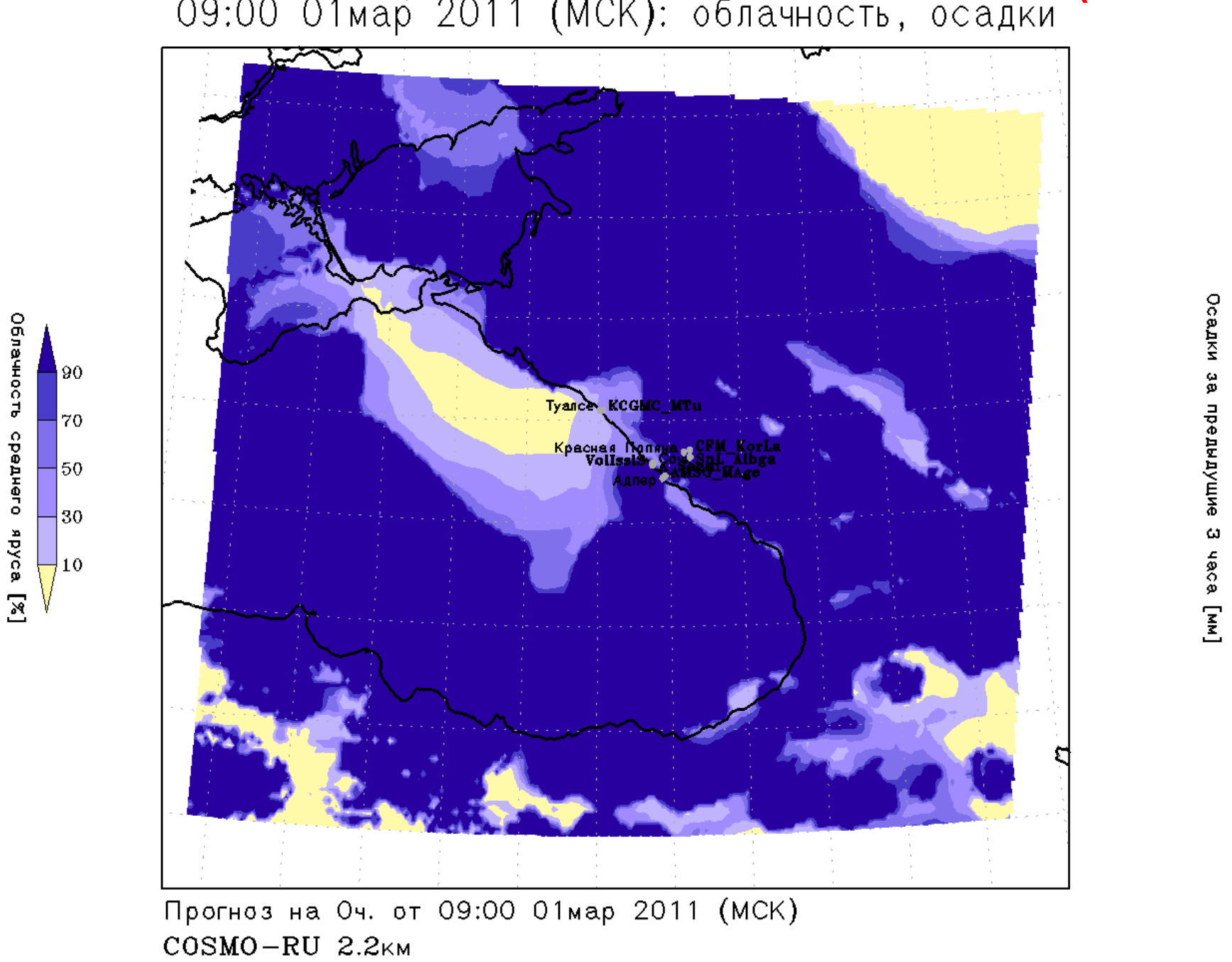
COSMO-RU02: Sochi, Initial data 01.03.2001 00 UTC (03 MSC)



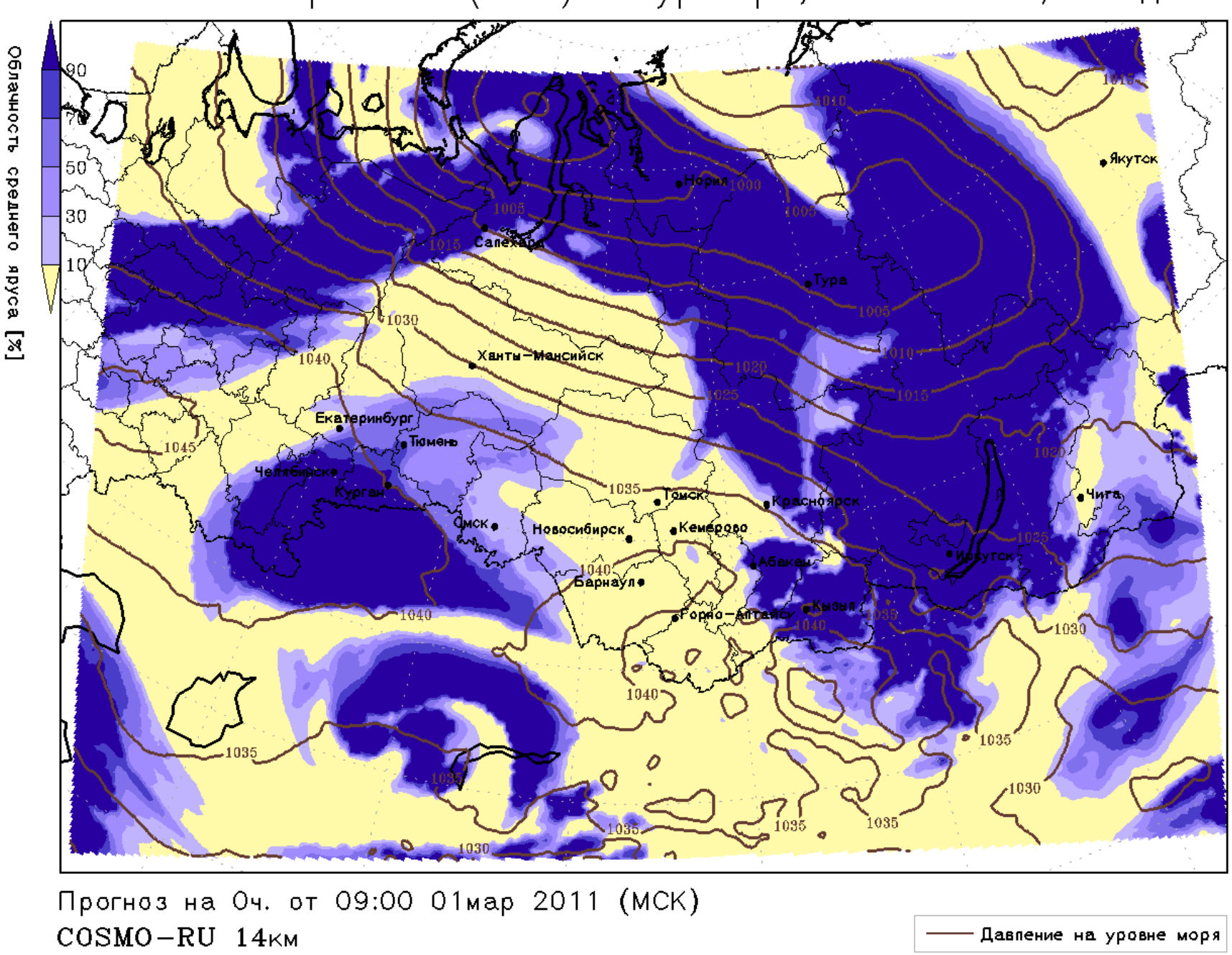
COSMO-RU07: Sochi, Initial data 01.03.2001 00 UTC (03 MSC)

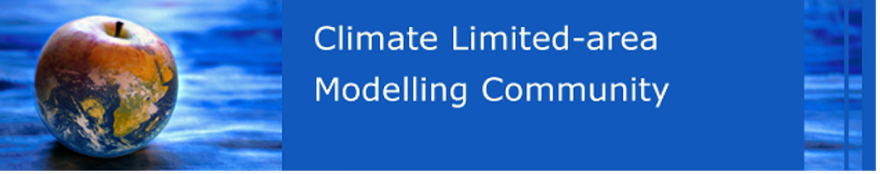


COSMO-RU02: Sochi, Initial data 01.03.2001 06 UTC (09 MSC)



COSMO-RU14: Siberia, Initial data 01.03.2001 06 UTC (09 MSC)





Afrika:

Tanzania Meteorol. Agency

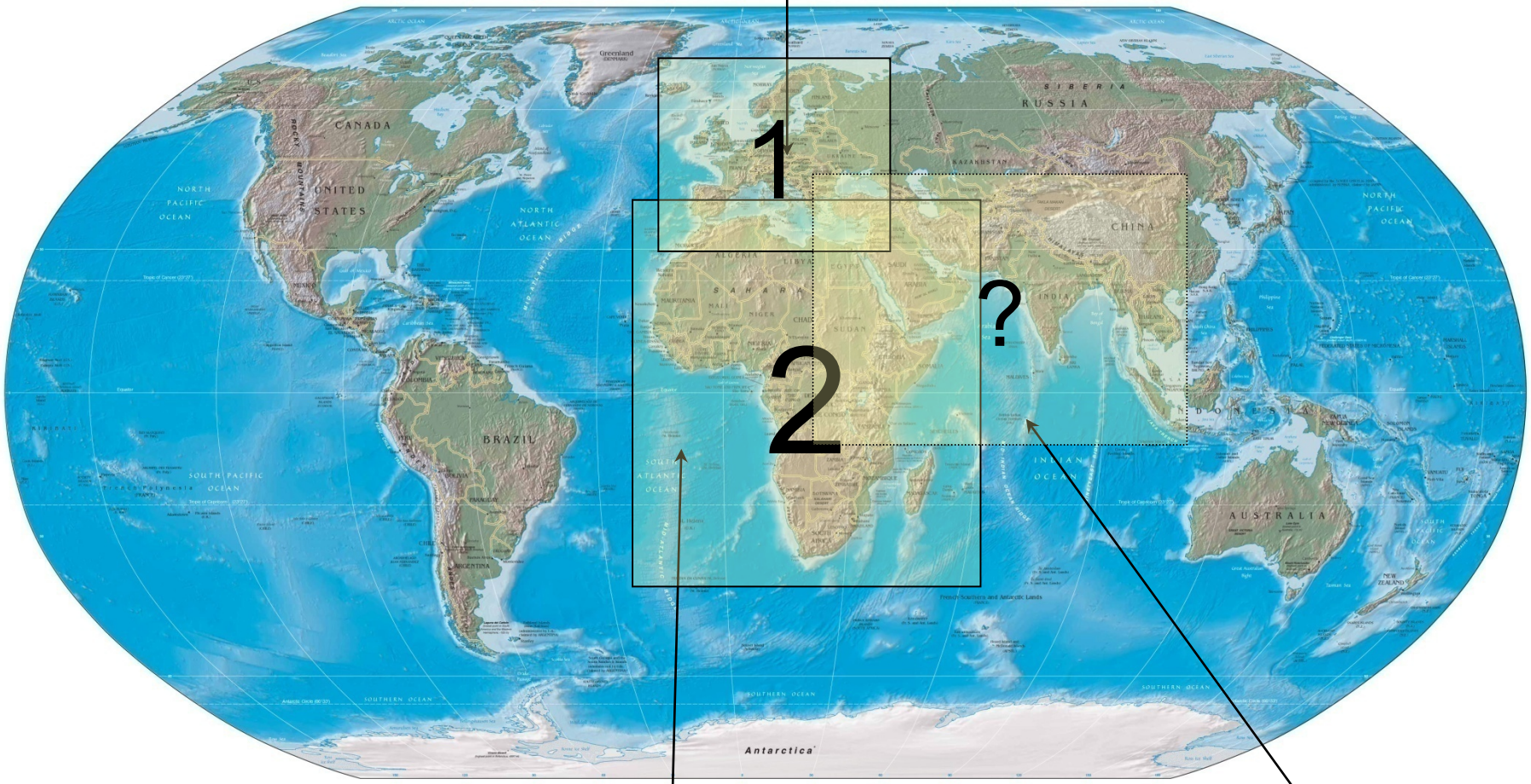
National Meteorol. Agency of Senegal

America

Universidad Nacional Autonoma de Mexico

>5

CCLM IPCC-AR5 Regions



CORDEX-Regions

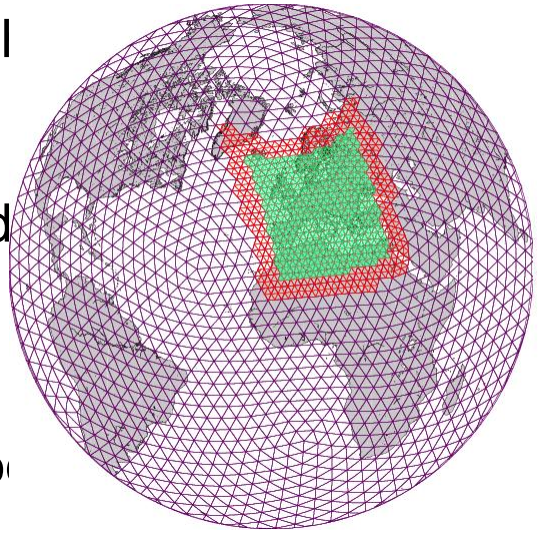
ICON – a joint project of MPI-M and DWD

- **ICO**sahedral **N**on-hydrostatic general circulation model with static local zooming option
- Atmosphere and ocean (stand-alone or coupled)
- Global and regional, or combined

Icosahedron

- **At DWD:**
  - Replace GME and COSMO-EU by ICON with a higl resolution window over Europe.
  - Establish a library of scale-adaptive physical parameterization schemes (to be used in ICON and COSMO-DE).
- **At MPI-M:**

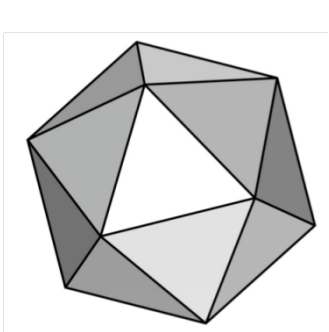
  Use ICON as dynamical core of an Earth System Mo (COSMOS)
  - replace regional climate model REMO.

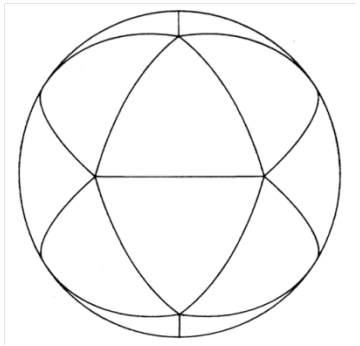


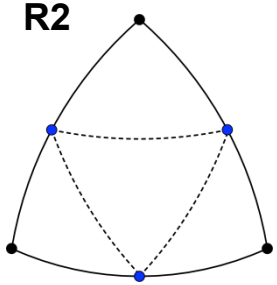
(Courtesy Günther Zängl, DWD)

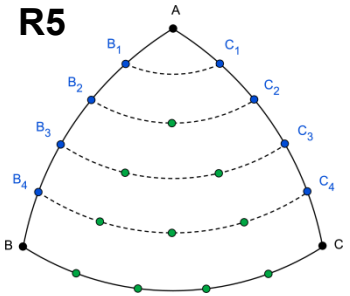
Icosahedral Grid

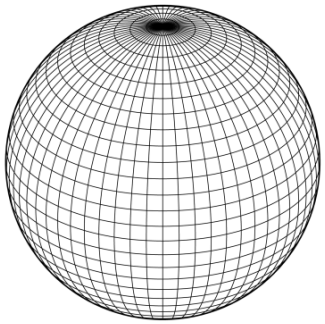
(Courtesy Hui Wan, MPI)

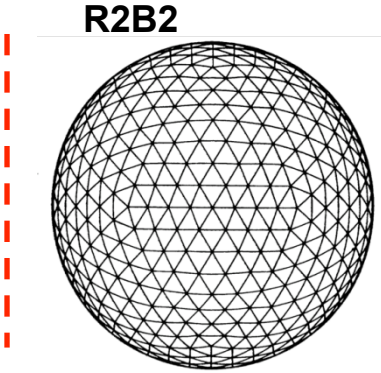


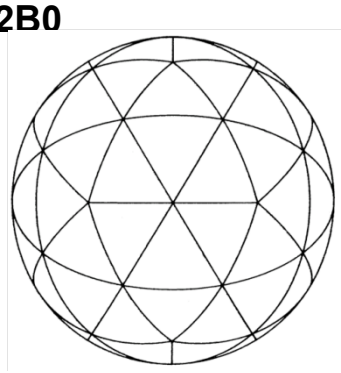






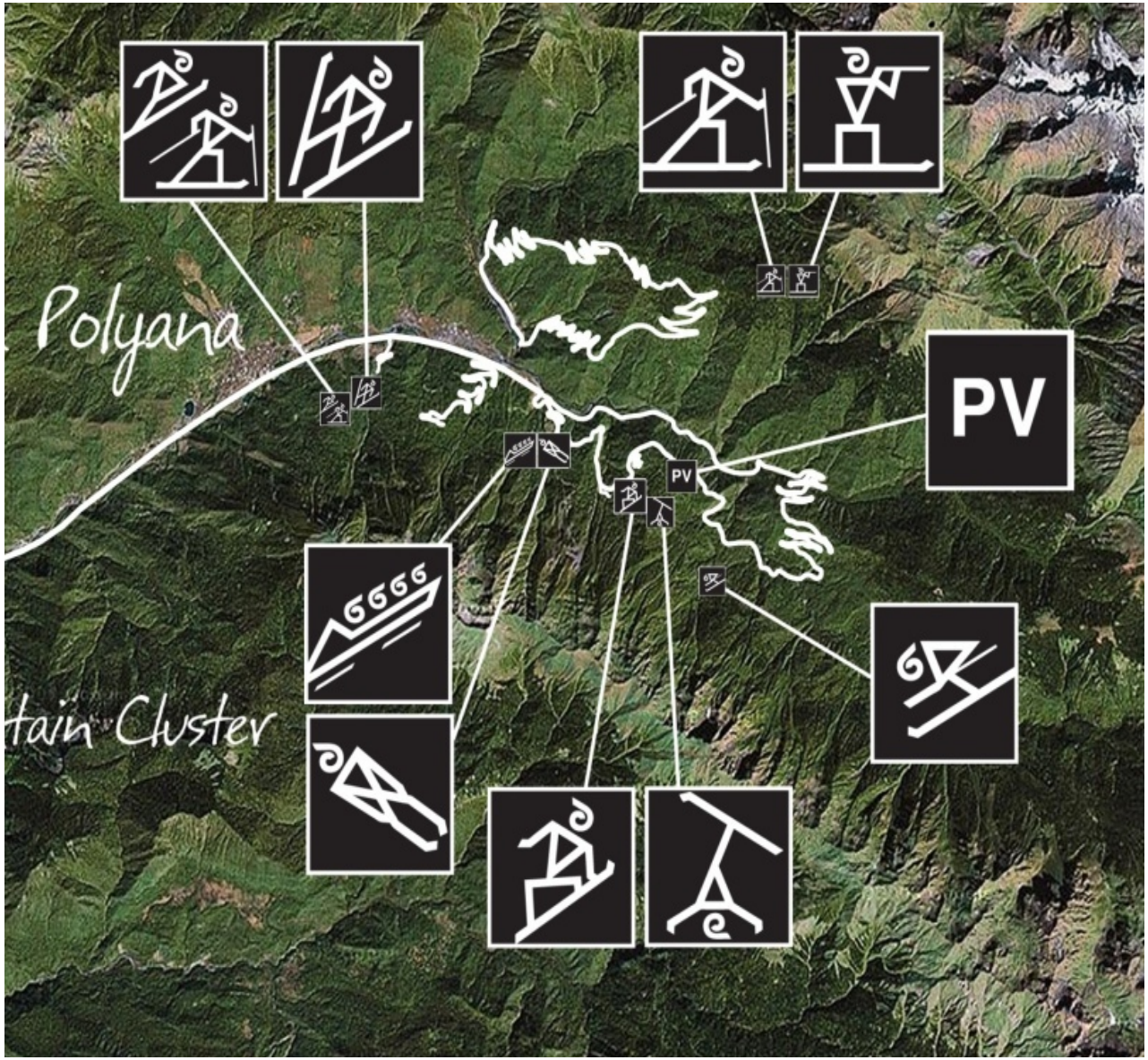






- grid optimization → s*pring dynamics*
- Ratio of min/max distance between neighboring cell centers: 55%±10% (resolution dependent)

Sochi 2014



Sochi 2014 and COSMO

- *COSMO* will be engaged
  in WWRP RDPs/FDPs for Sochi 2014.

- There are four components, namely
  1. *deterministic, very high resolution NWP* in rapid update cycle mode,
  2. *probabilistic, high resolution downscaling of ECMWF EPS,*
  3. *user-oriented postprocessing,*
  4. *conditional verification scheme.*

- *Russia, Germany, Switzerland* and *Italy* will contribute to the work.

- Pre-operational trial of components should start by the end of 2011/2012.

THE NONHYDROSTATIC SHORT-RANGE MESOSCALE WEATHER FORECAST SYSTEM COSMO-RU : CURRENT STATUS and PROSPECTS

Thanks for the attention !

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09 July 2011, Tomsk